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Robinson

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(54) **METHOD FOR TRANSPORTING COMPONENTS USING A GRIPPER HEAD APPARATUS**

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B25J 15/06 (2006.01)
B65G 17/32 (2006.01)

(52) **U.S. Cl.**
CPC ***B65G 47/911*** (2013.01); ***B25J 15/0616*** (2013.01); ***B65G 47/917*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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(57) **ABSTRACT**

A method is provided for transporting components using a gripping apparatus. The gripping apparatus includes a body defining a chamber and includes an exhaust at a first end of the body. The gripping apparatus also includes an air conveyor positioned within the chamber. The method includes attaching a gripper head to a second end of the body opposite to the first end. The gripper head defines one or more openings and a nest. The method further includes generating an air flow through an inlet of the air conveyor and out through the exhaust. The method further includes applying suction via the one or more openings in the gripper head to locate and releasably hold one of the components with the gripper head at the first location based on the generating step. The method further includes transporting the component from the first location to a second location.

18 Claims, 13 Drawing Sheets

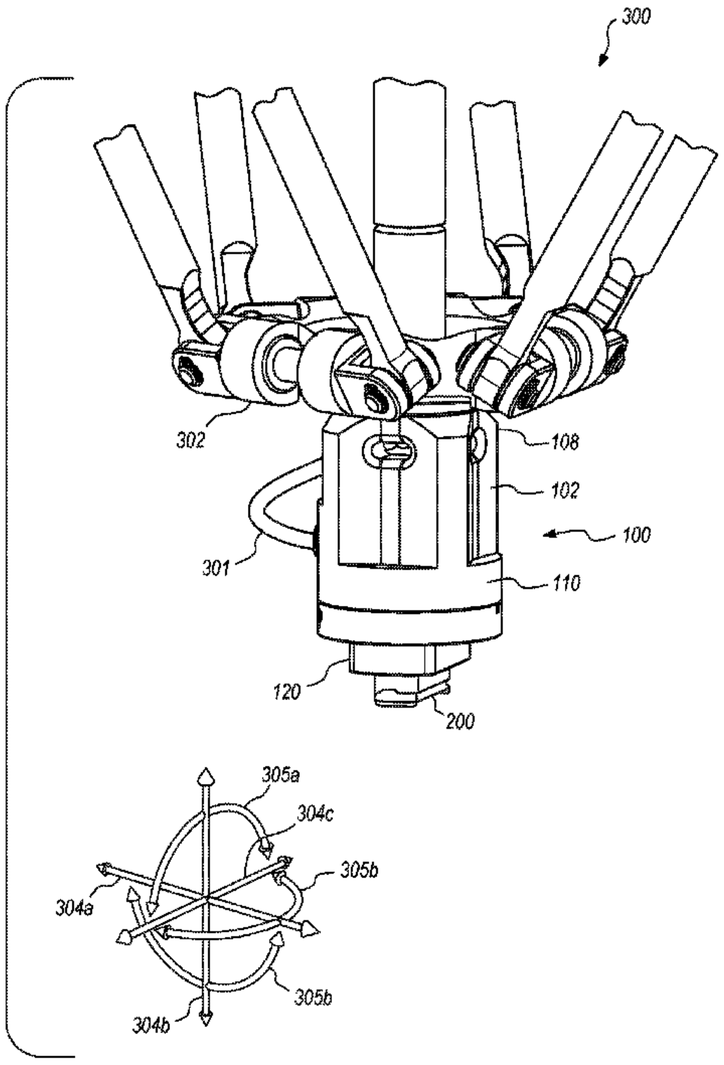


FIG. 1A

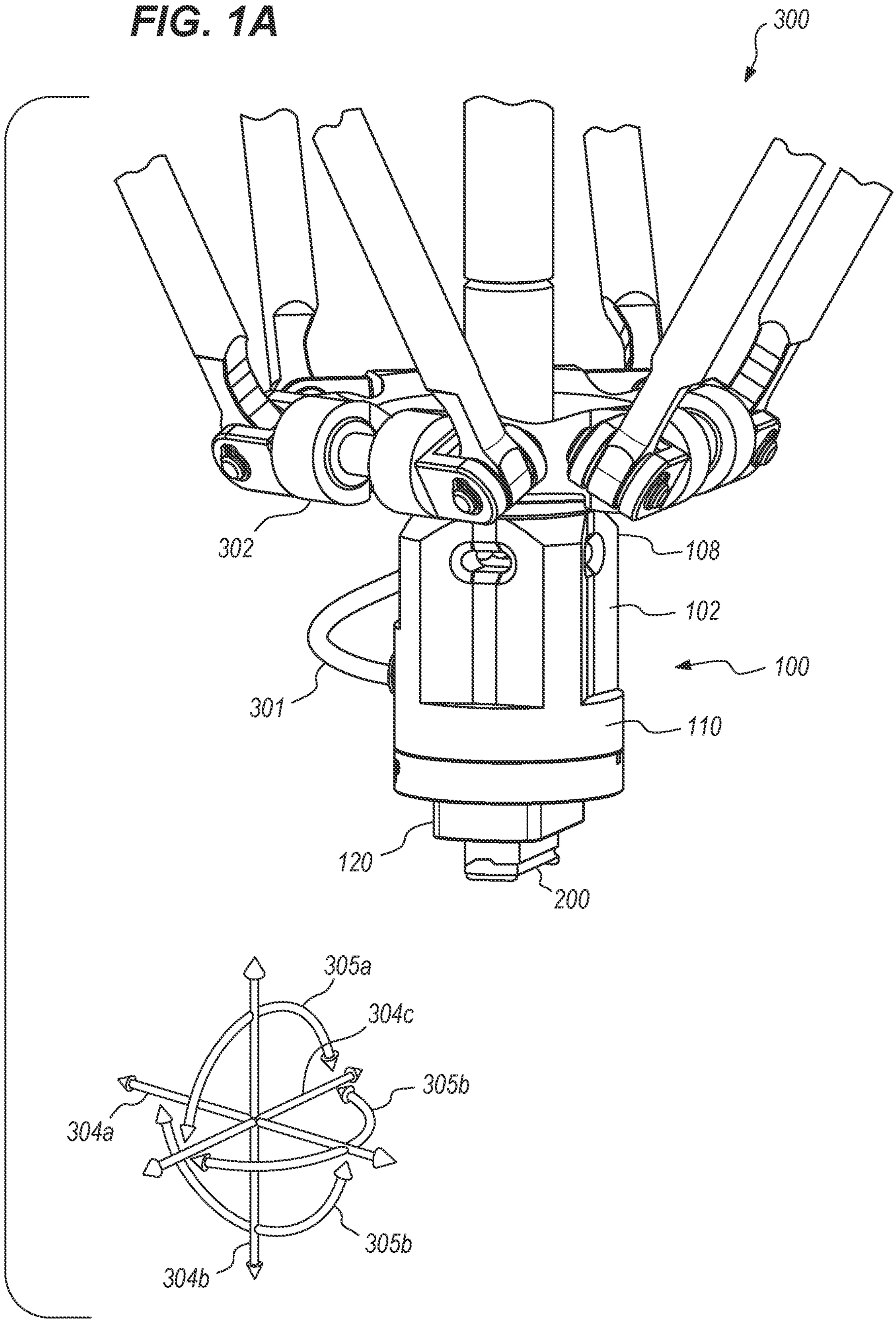

300
302
108
102
100
301
110
120
200
305a
304c
305b
304a
305b
304b

FIG. 1B

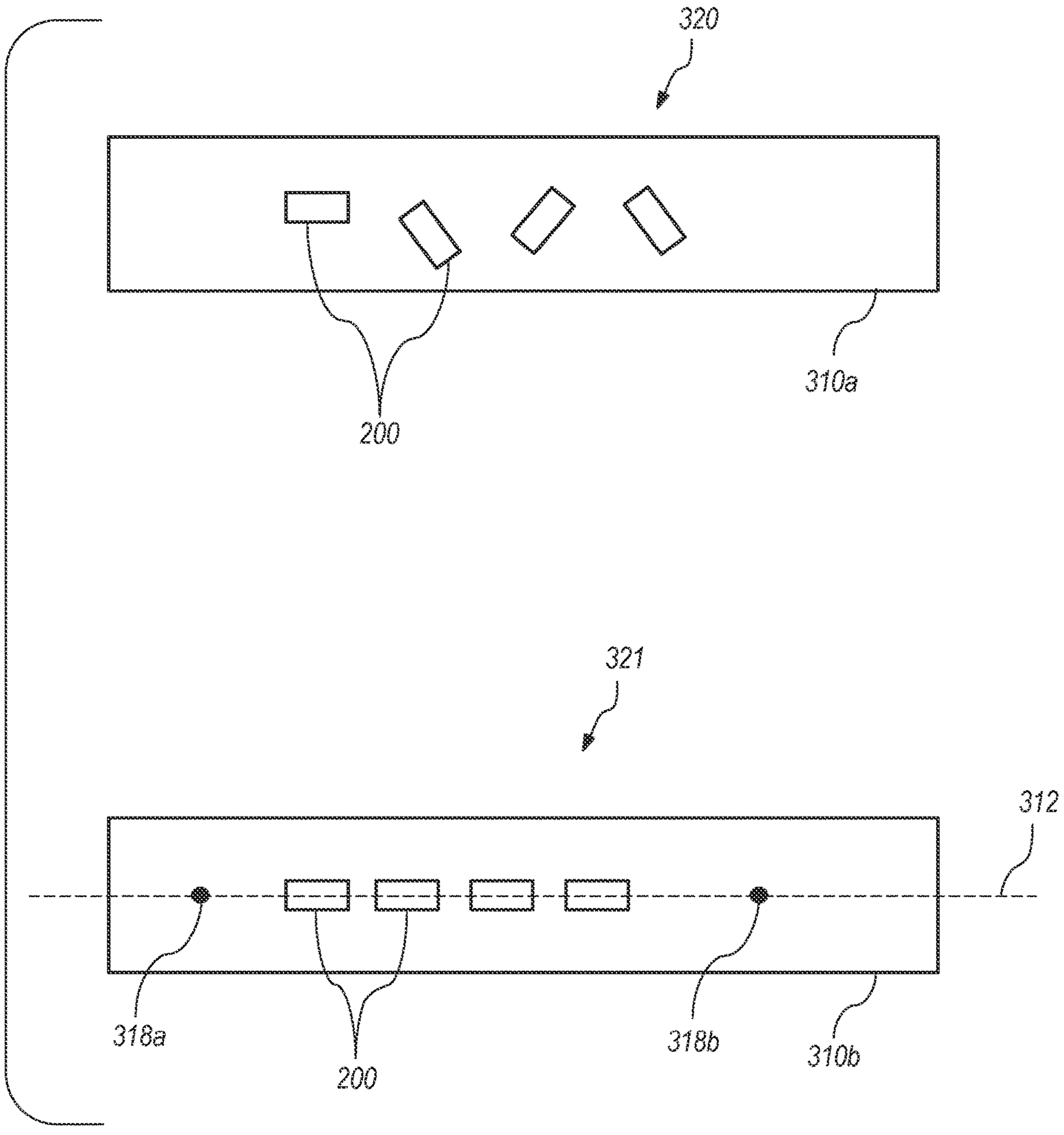


FIG. 2

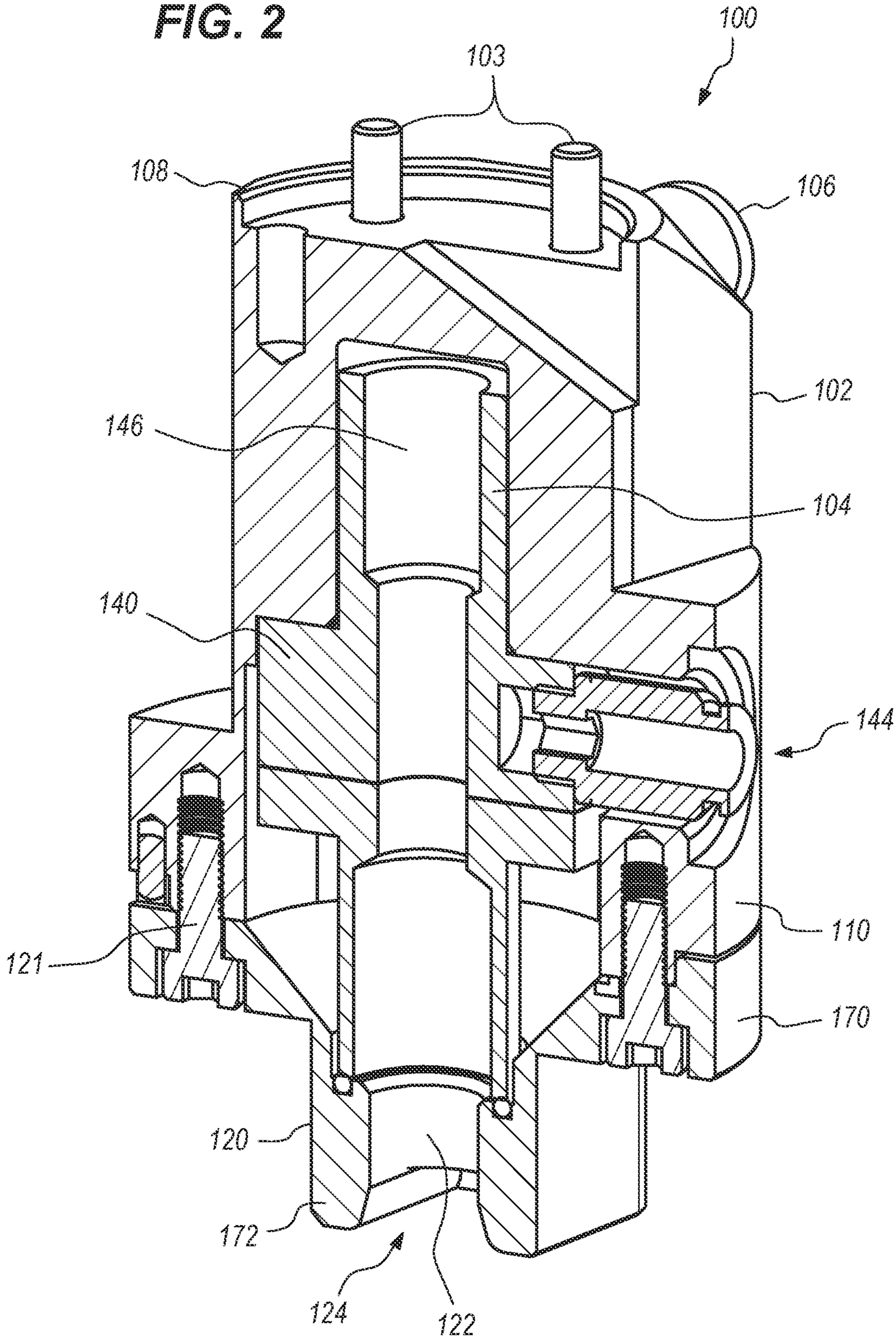


FIG. 3A

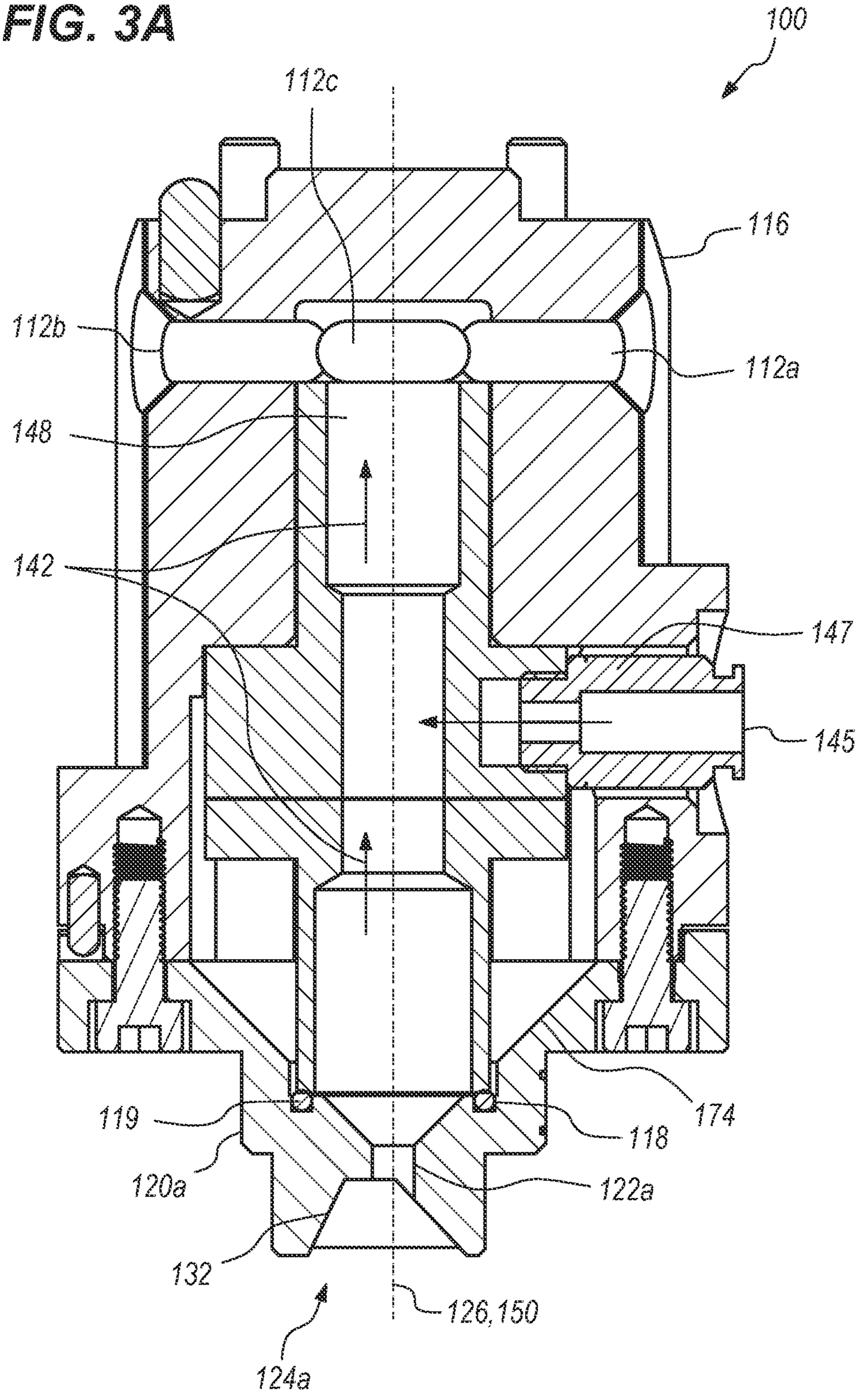

100
112c
116
112b
112a
148
142
147
145
119
118
174
120a
122a
132
126,150
124a

FIG. 3B

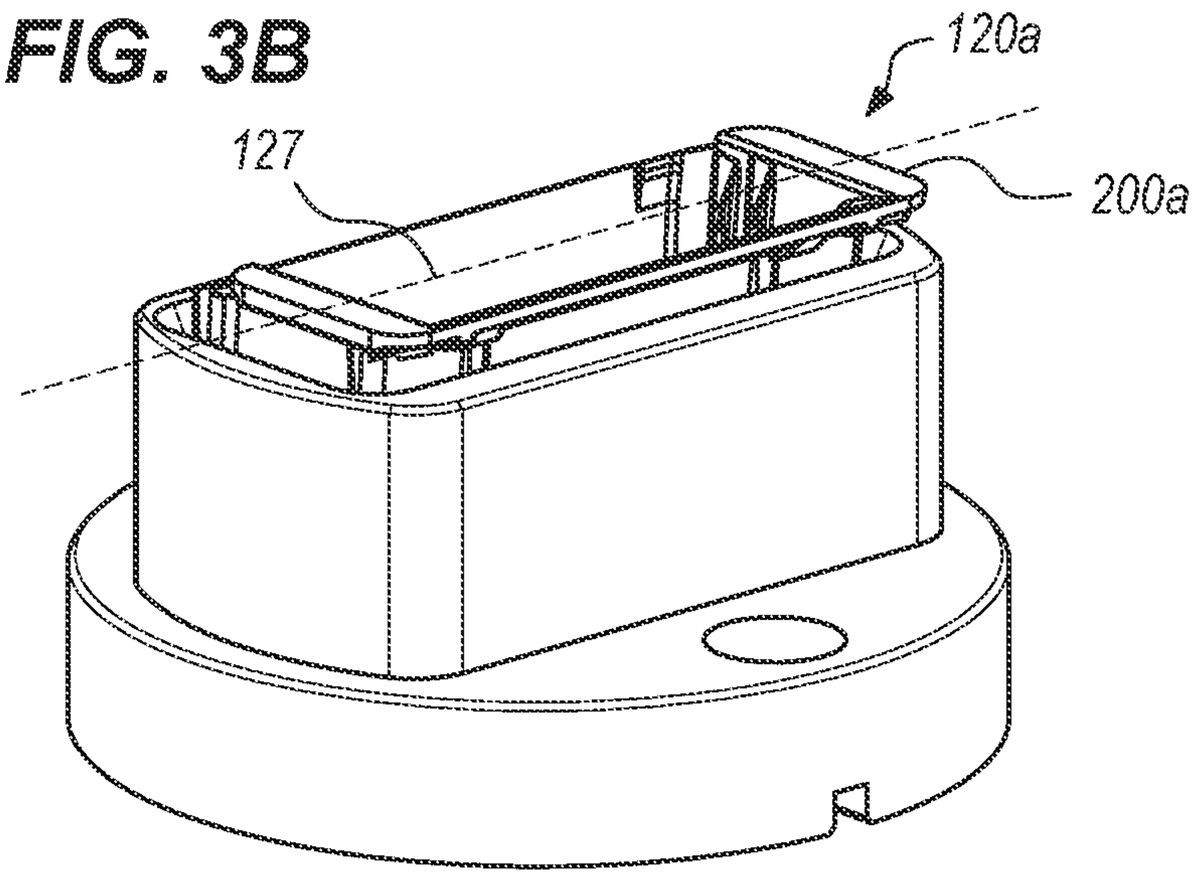


FIG. 3C

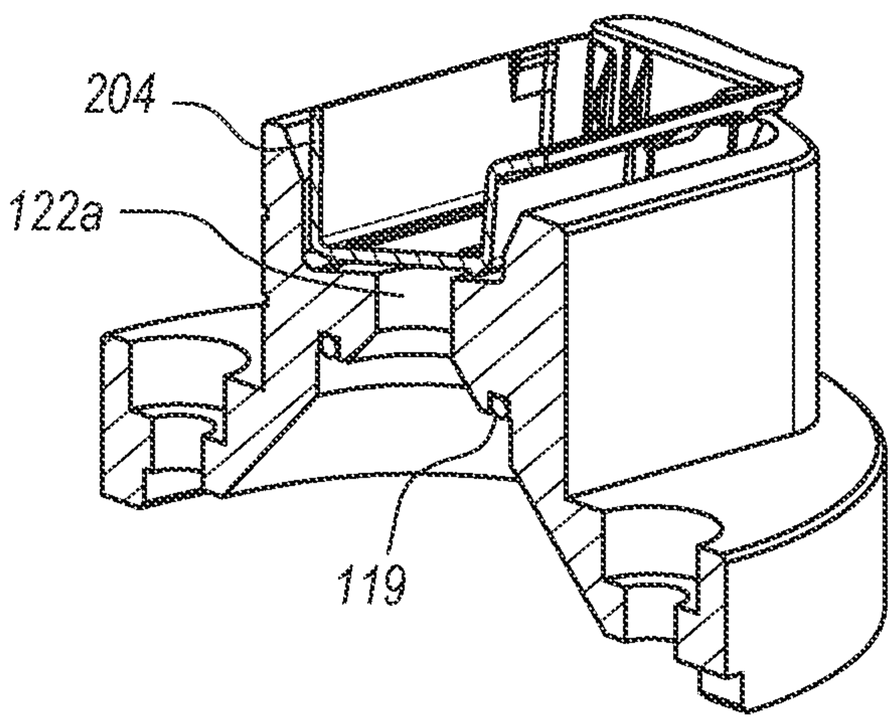


FIG. 3D

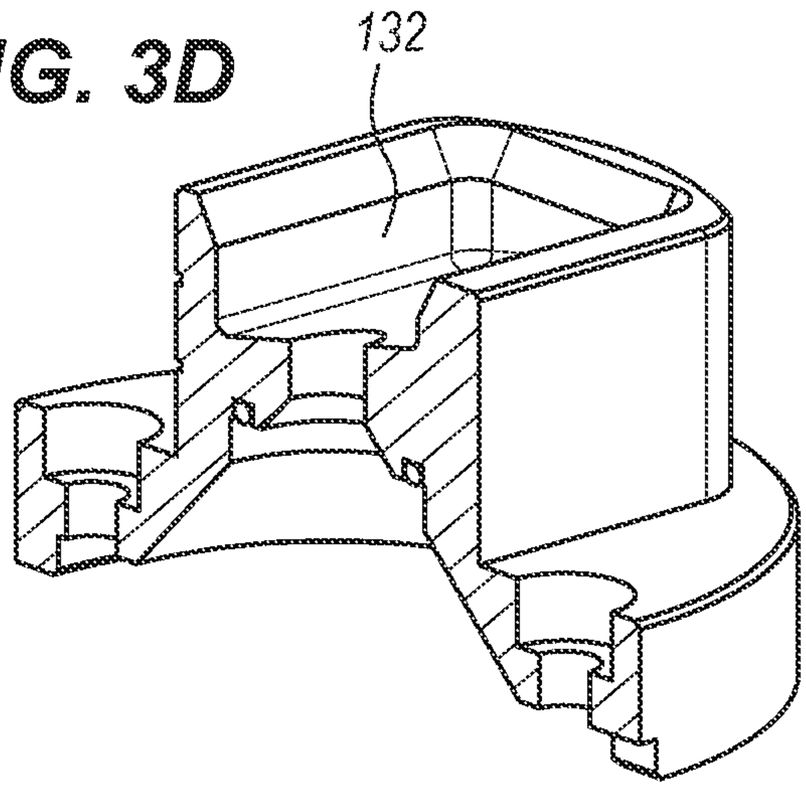


FIG. 4A

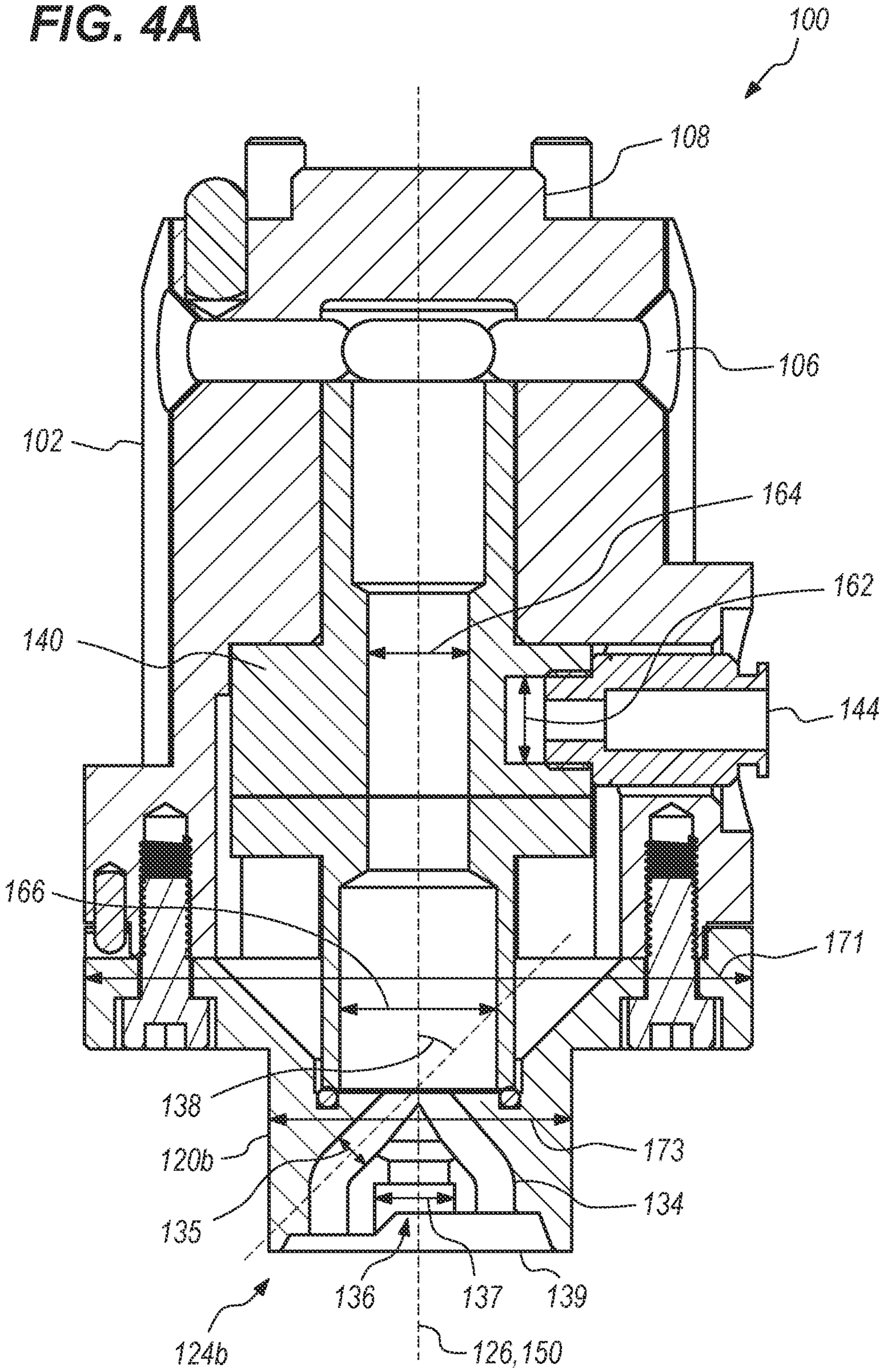

100
108
106
102
164
162
140
144
166
171
138
120b
135
173
134
136
137
139
124b
126,150

FIG. 4B

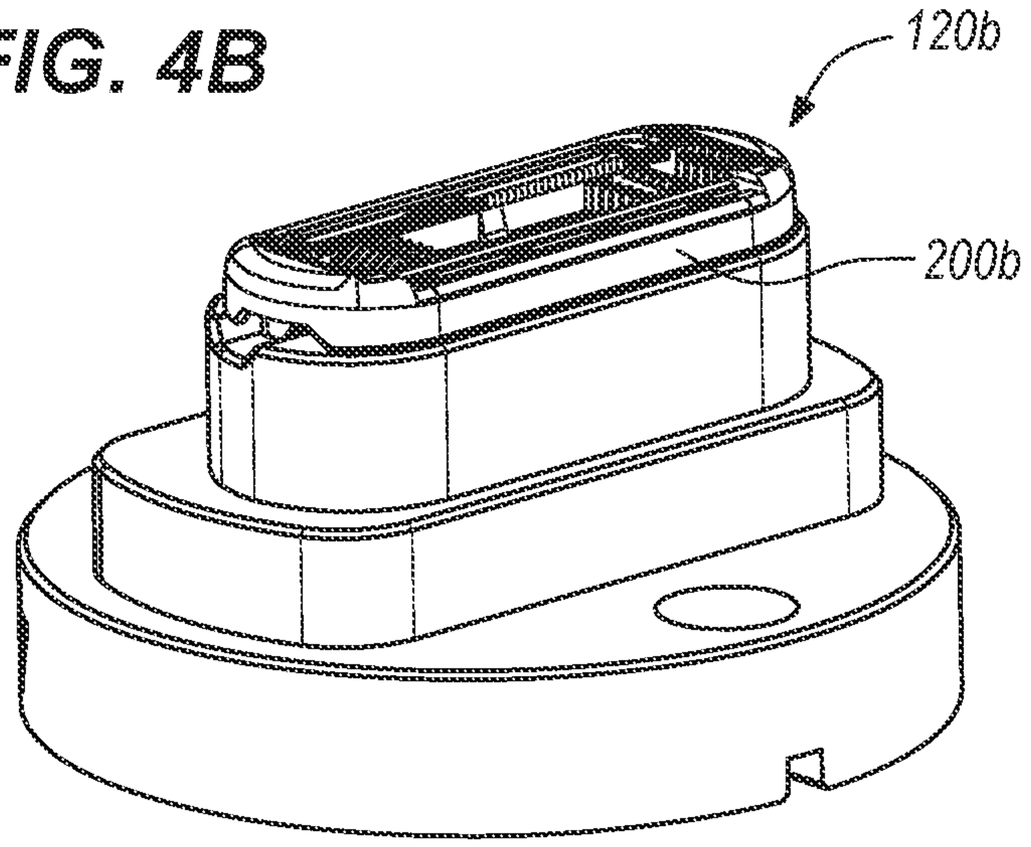


FIG. 4C

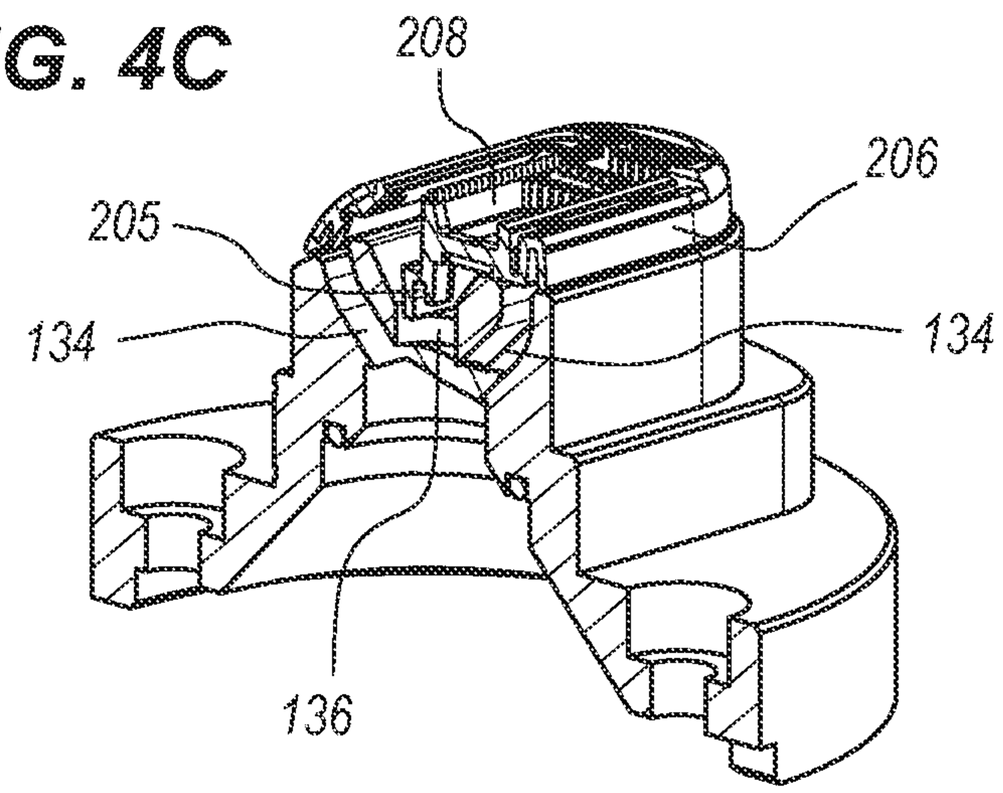


FIG. 4D

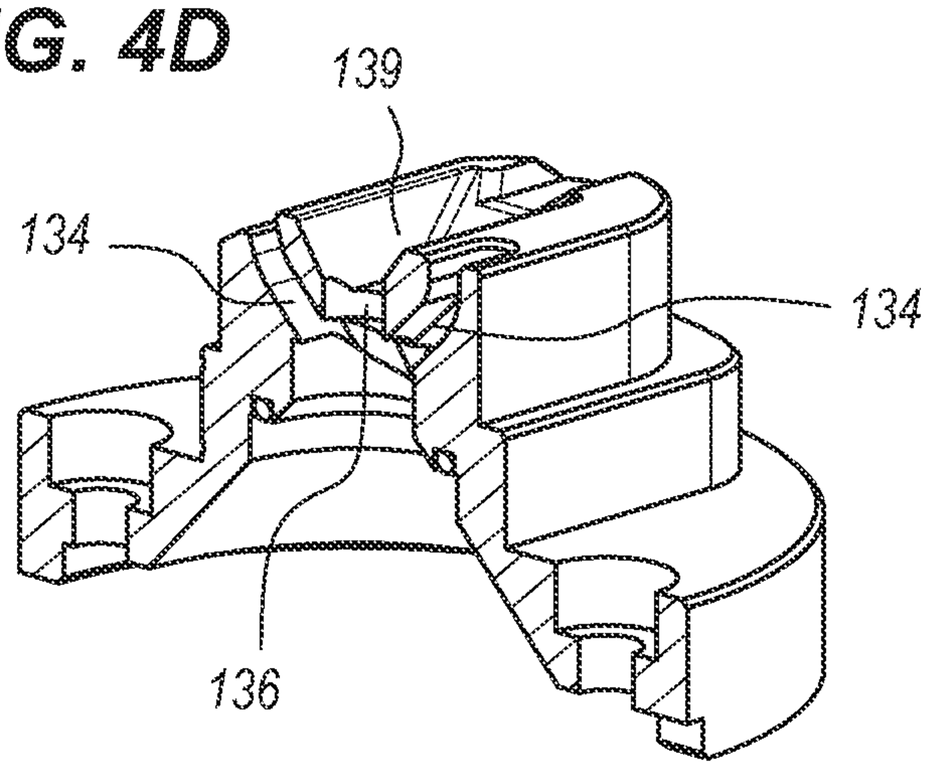


FIG. 5A

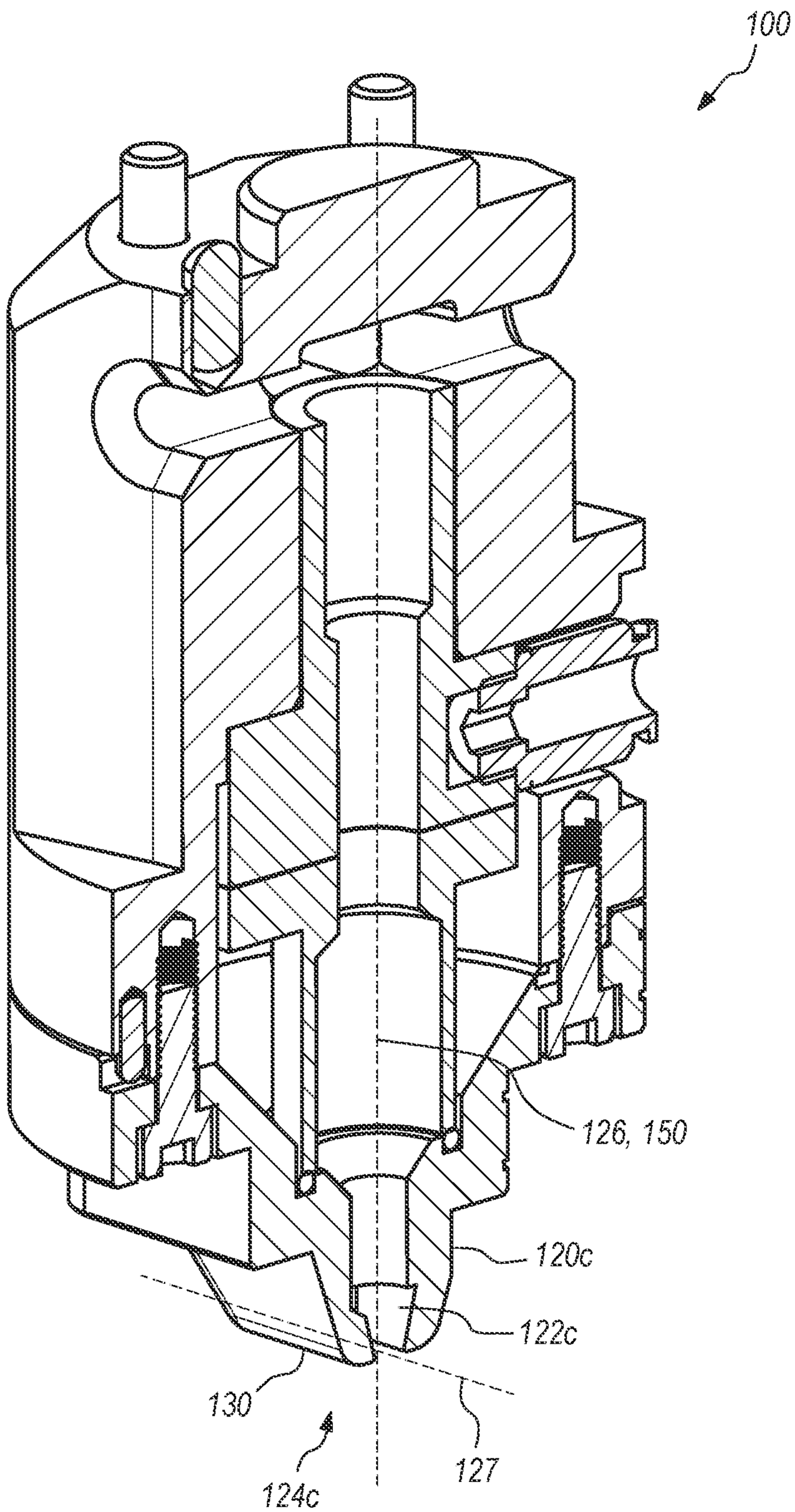


FIG. 5B

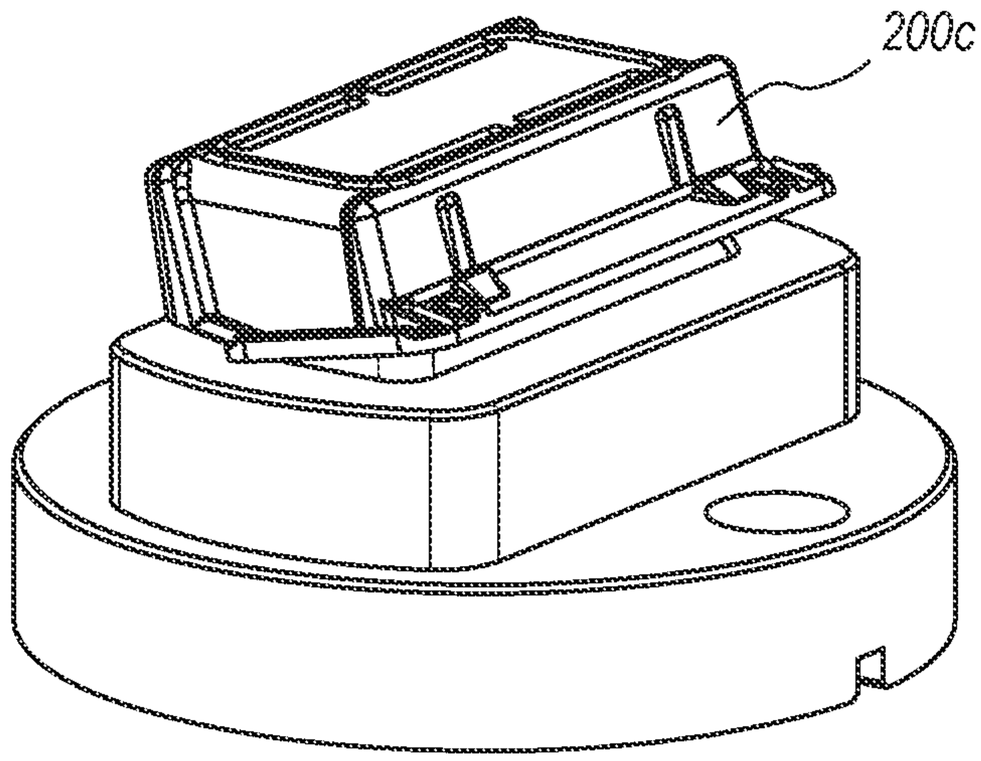


FIG. 5C

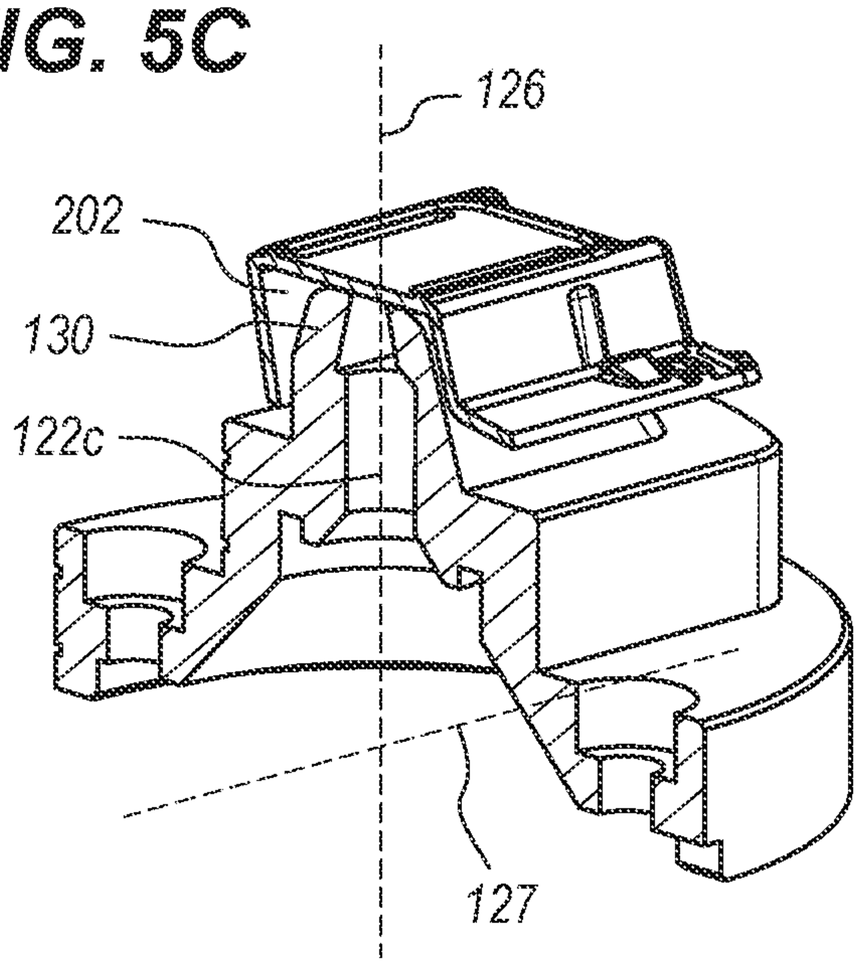


FIG. 6

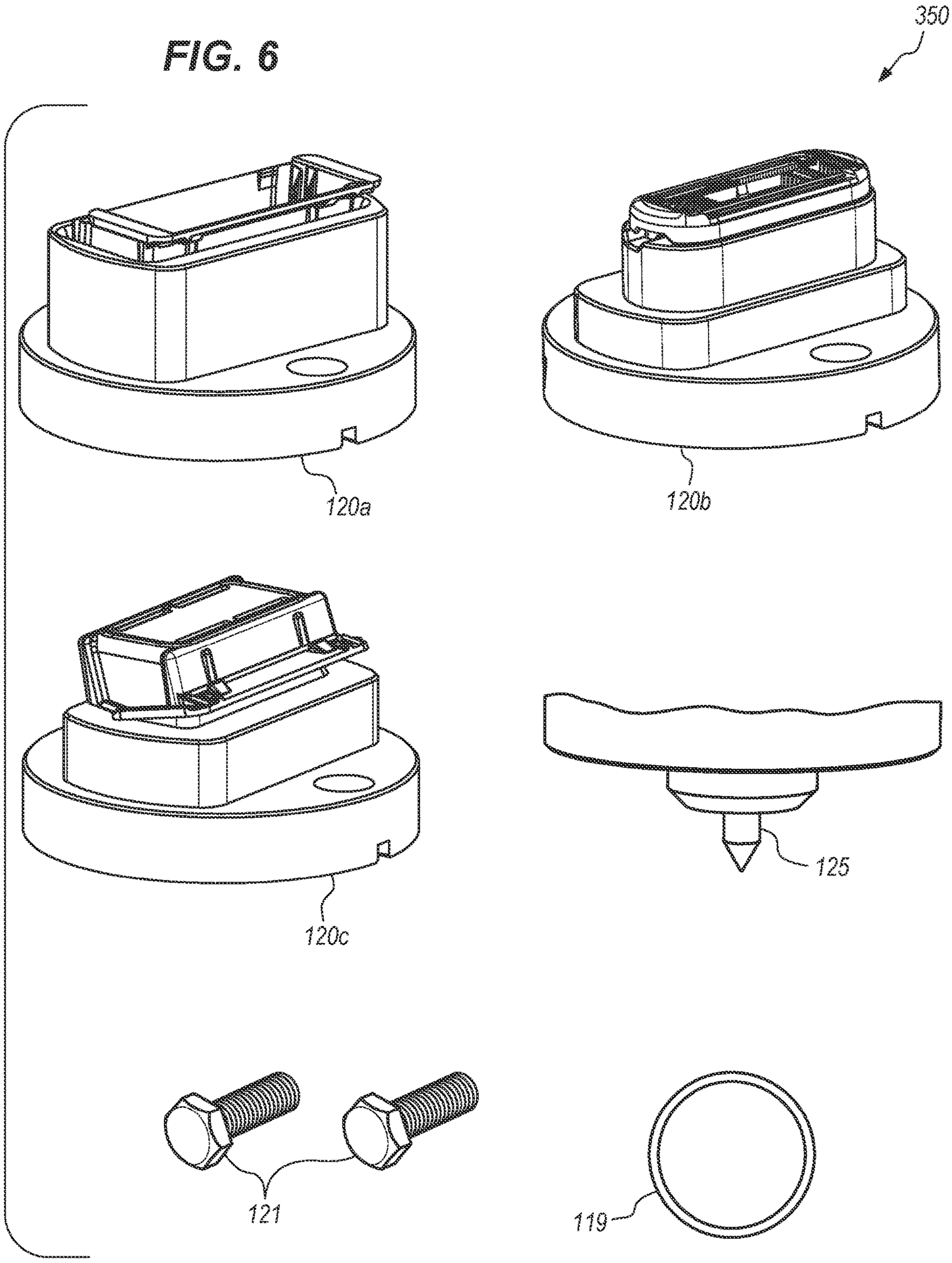


FIG. 7

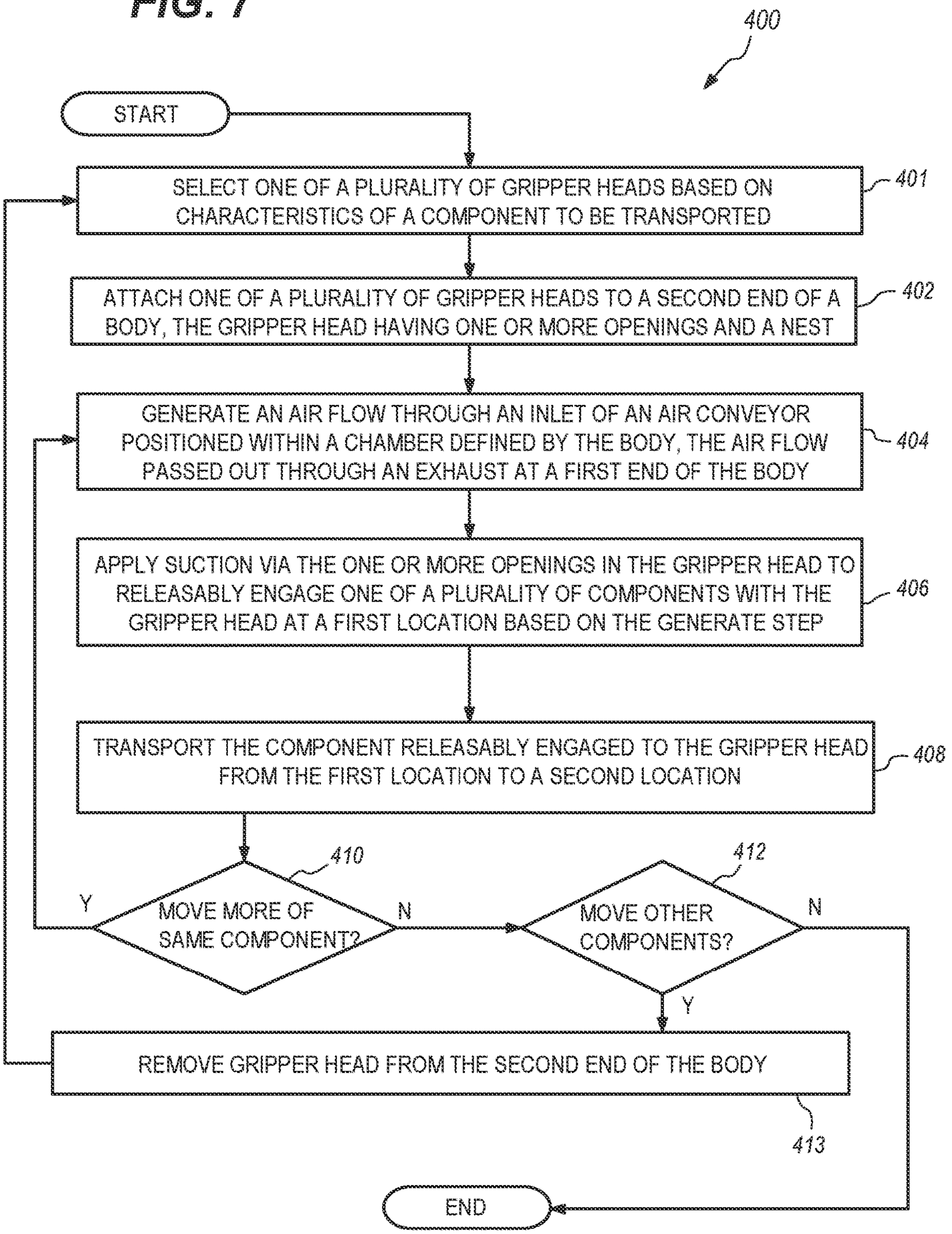

400
START
SELECT ONE OF A PLURALITY OF GRIPPER HEADS BASED ON CHARACTERISTICS OF A COMPONENT TO BE TRANSPORTED
401
ATTACH ONE OF A PLURALITY OF GRIPPER HEADS TO A SECOND END OF A BODY, THE GRIPPER HEAD HAVING ONE OR MORE OPENINGS AND A NEST
402
GENERATE AN AIR FLOW THROUGH AN INLET OF AN AIR CONVEYOR POSITIONED WITHIN A CHAMBER DEFINED BY THE BODY, THE AIR FLOW PASSED OUT THROUGH AN EXHAUST AT A FIRST END OF THE BODY
404
APPLY SUCTION VIA THE ONE OR MORE OPENINGS IN THE GRIPPER HEAD TO RELEASABLY ENGAGE ONE OF A PLURALITY OF COMPONENTS WITH THE GRIPPER HEAD AT A FIRST LOCATION BASED ON THE GENERATE STEP
406
TRANSPORT THE COMPONENT RELEASABLY ENGAGED TO THE GRIPPER HEAD FROM THE FIRST LOCATION TO A SECOND LOCATION
408
410
MOVE MORE OF SAME COMPONENT?
Y
N
412
MOVE OTHER COMPONENTS?
N
Y
REMOVE GRIPPER HEAD FROM THE SECOND END OF THE BODY
413
END

FIG. 8

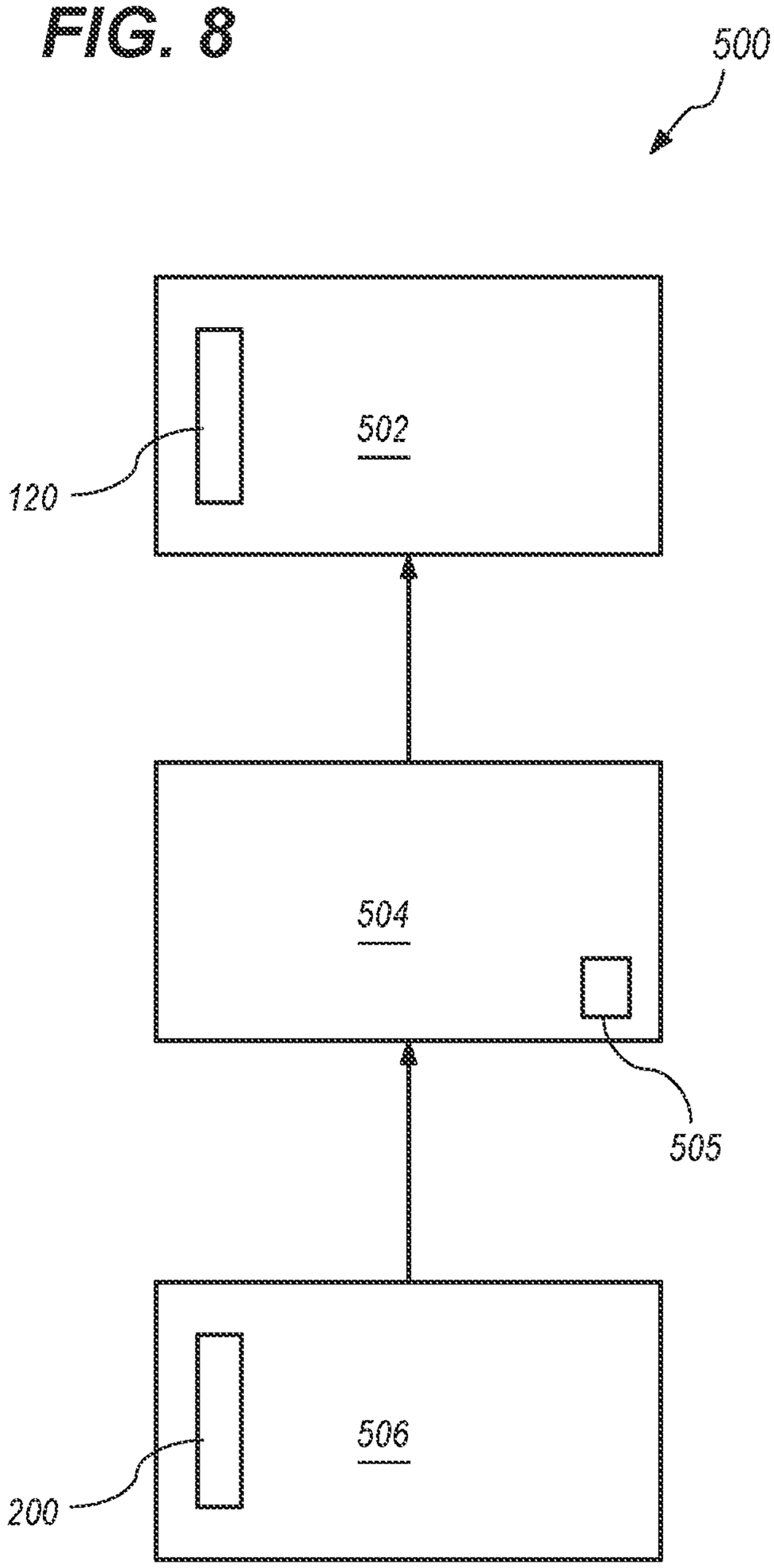
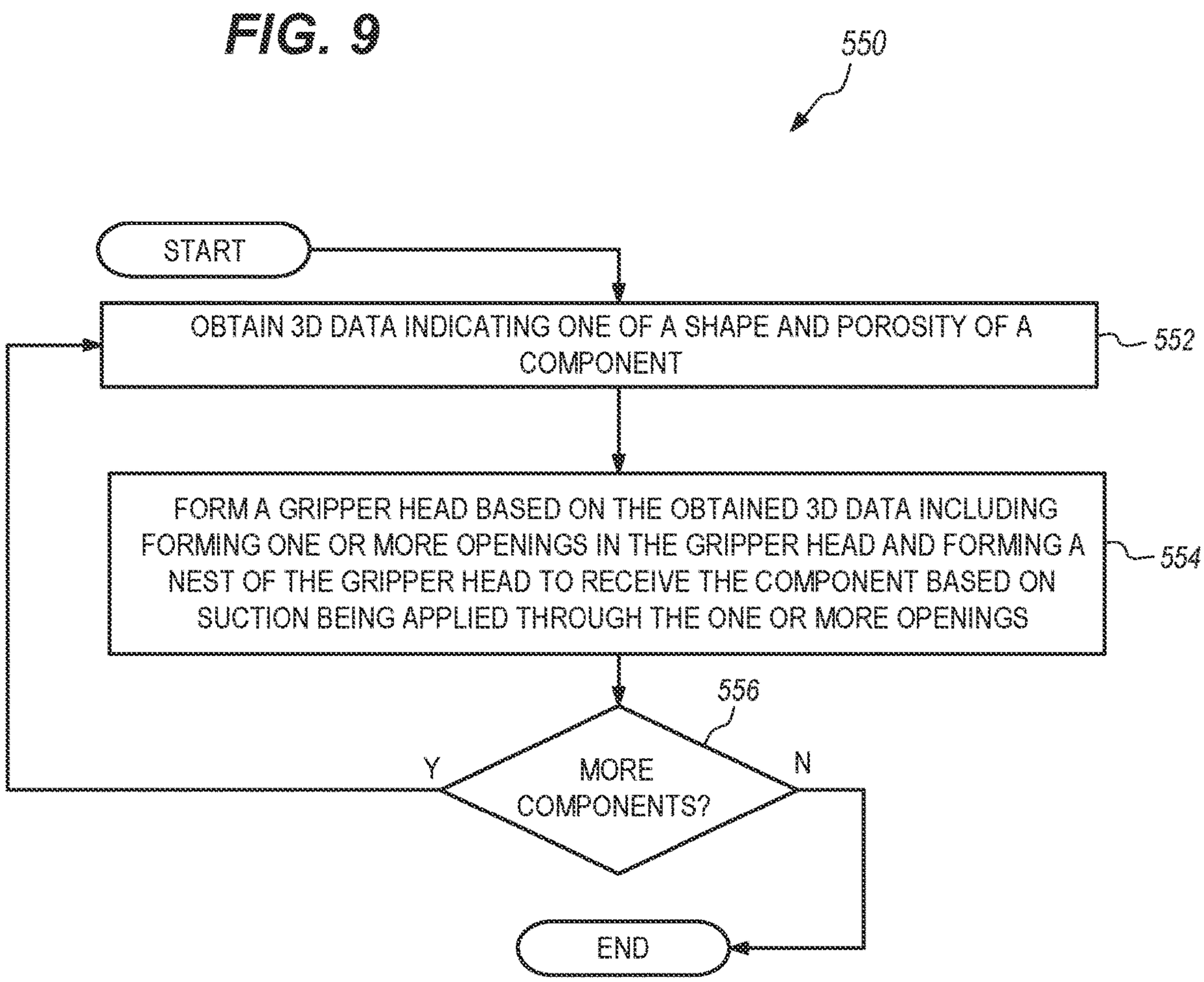


FIG. 9


550
START
OBTAIN 3D DATA INDICATING ONE OF A SHAPE AND POROSITY OF A COMPONENT
552
FORM A GRIPPER HEAD BASED ON THE OBTAINED 3D DATA INCLUDING FORMING ONE OR MORE OPENINGS IN THE GRIPPER HEAD AND FORMING A NEST OF THE GRIPPER HEAD TO RECEIVE THE COMPONENT BASED ON SUCTION BEING APPLIED THROUGH THE ONE OR MORE OPENINGS
554
556
MORE COMPONENTS?
Y
N
END

METHOD FOR TRANSPORTING COMPONENTS USING A GRIPPER HEAD APPARATUS

FIELD

The present disclosure relates generally to grippers used in conjunction with vacuum generators to suction components in order to transport them from one location to another.

BACKGROUND

Standard suction cups or mechanical grippers are available which are used in conjunction with vacuum generators to suction one or more components and transport them from one location to another. However, these standard suction cups require the component have a minimum surface area in order to generate the necessary suction to hold the component. Additionally, these standard suction cups only work with components capable of withstanding a threshold suction force established by the suction cup. Hence, these conventional suction cups are not suitable for transporting components that have minimal surface area and/or which are delicate and not capable of withstanding these threshold suction forces.

Additionally, in addition to a primary valve that is used to establish the vacuum suction, these standard suction cups typically feature a secondary valve to provide an ejection pulse to release the component from the suction cup after transport. Hence, by introducing these secondary valves, these conventional suction cups increase a cycle time of the unit in transporting components between locations.

These conventional suction cups also require a large suction rate that necessitates an increased weight and size of the end of an arm tooling on which the suction cup is positioned. This increased size and weight necessarily reduces the performance of the system.

SUMMARY

Various embodiments solve the above-mentioned problems and provide a gripper head apparatus for transporting components from one location to another, especially those components having a minimal surface area or are delicate such that they are not capable of withstanding threshold suction forces established by conventional suction cups. Various embodiments also provide a kit including a plurality of gripper heads to be used with the gripper head apparatus. Various embodiments also provide a method for transporting components from one location to another using the gripper head apparatus. Various embodiments also provide a method for forming multiple gripper heads for use in the method for transporting the components.

In a first set of embodiments, a gripping apparatus is provided for transporting components from one location to another. The gripping apparatus includes a body defining a chamber and an exhaust at a first end of the body. The apparatus also includes a gripper head configured to be attached to a second end of the body opposite to the first end. The gripper head defines one or more openings and a nest having a profile configured to locate and releasably hold a component based on an air flow generated within the chamber and discharged through the exhaust. The apparatus also includes an air conveyor positioned within the chamber. The air conveyor is configured to generate the air flow through an inlet and out through the exhaust. The air conveyor defines a central bore and an exhaust port. The inlet includes an inlet port with a nozzle in communication with the central bore and the exhaust port.

In a second set of embodiments, a kit is provided for a gripping apparatus. The gripping apparatus includes a body defining a chamber and an exhaust at a first end of the body. The gripping apparatus also includes an air conveyor positioned within the chamber. The air conveyor is configured to generate an air flow through an inlet and out through the exhaust. The kit includes a plurality of gripper heads each configured to be attached to a second end of the body opposite to the first end. Each gripper head defines a respective interchangeable nest that is different among the plurality of gripper heads. Each gripper head is configured to locate and releasably hold one of a plurality of components based on the air flow generated within the chamber and discharged through the exhaust.

In a third set of embodiments, a method is provided for transporting components from a first location to a second location using a gripping apparatus. The gripping apparatus includes a body defining a chamber and includes an exhaust at a first end of the body. The gripping apparatus also includes an air conveyor positioned within the chamber. The method includes attaching one of a plurality of gripper heads to a second end of the body opposite to the first end. The gripper head defines one or more openings and a nest. The method further includes generating an air flow through an inlet of the air conveyor and out through the exhaust. The method further includes applying suction via the one or more openings in the gripper head to locate and releasably hold one of the plurality of components with the gripper head at the first location based on the generating step. The method further includes transporting the component releasably held to the gripper head from the first location to a second location.

In a fourth set of embodiments, a method is provided for forming one or more gripper heads to be used with a gripping apparatus. The method includes obtaining 3D data based on a geometry of a component. The method also includes forming one gripper head comprising 3D printing the gripper head based on the obtained 3D data. The forming step includes forming one or more openings in the gripper head and forming a nest of the gripper head to locate and releasably hold the component based on suction being applied through the one or more openings.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of this disclosure can be better understood with reference to the following figures.

FIG. **1**A is an example according to various embodiments illustrating a side perspective view of an automated system that is used to move a gripper head apparatus in one or more directions.

FIG. **1**B is an example according to various embodiments illustrating a top view of components being moved from a first location to a second location with the automated system of FIG. **1**A.

FIG. **2** is an example according to various embodiments illustrating a sectional perspective view of a gripping apparatus including a gripper head to releasably hold a component.

FIG. **3**A is an example according to various embodiments illustrating a cross-sectional side view of a gripping apparatus including a gripper head to releasably hold a component.

FIGS. **3**B through **3**D is an example according to various embodiments illustrating perspective views of the gripper head of FIG. **3**A to releasably hold the component.

FIG. **4**A is an example according to various embodiments illustrating a cross-sectional side view of a gripping apparatus including a gripper head to releasably hold a component.

FIGS. **4**B through **4**D is an example according to various embodiments illustrating perspective views of the gripper head of FIG. **4**A to releasably hold the component.

FIG. **5**A is an example according to various embodiments illustrating a cross-sectional side view of a gripping apparatus including a gripper head to releasably hold a component.

FIGS. **5**B through **5**C is an example according to various embodiments illustrating perspective views of the gripper head of FIG. **5**A to releasably hold the component.

FIG. **6** is an example according to various embodiments illustrating a kit for a gripping apparatus including multiple gripper heads used to transport multiple components from a first location to a second location.

FIG. **7** is an example according to various embodiments illustrating a flowchart of a method for transporting one or more components using one or more gripper heads of the kit of FIG. **6**.

FIG. **8** is an example according to various embodiments illustrating a system for 3D printing one or more gripper heads of the kit of FIG. **6**.

FIG. **9** is an example according to various embodiments illustrating a flowchart of a method for forming the one or more gripper heads using the system of FIG. **8**.

It should be understood that the various embodiments are not limited to the examples illustrated in the figures.

DETAILED DESCRIPTION

Introduction and Definitions

This disclosure is written to describe the invention to a person having ordinary skill in the art, who will understand that this disclosure is not limited to the specific examples or embodiments described. The examples and embodiments are single instances of the invention which will make a much larger scope apparent to the person having ordinary skill in the art. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by the person having ordinary skill in the art. It is also to be understood that the terminology used herein is for the purpose of describing examples and embodiments only, and is not intended to be limiting, since the scope of the present disclosure will be limited only by the appended claims.

All the features disclosed in this specification (including any accompanying claims, abstract, and drawings) may be replaced by alternative features serving the same, equivalent, or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features. The examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to the person having ordinary skill in the art and are to be included within the spirit and purview of this application. Many variations and modifications may be made to the embodiments of the disclosure without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure. For example, unless otherwise indicated, the present disclosure is not limited to particular materials, reagents, reaction materials, manufacturing processes, or the like, as such can vary. It is also to be understood that the terminology used herein is for purposes of describing particular embodiments only and is not intended to be limiting. It is also possible in the present disclosure that steps can be executed in different sequence where this is logically possible.

All numeric values are herein assumed to be modified by the term "about," whether or not explicitly indicated. The term "about" generally refers to a range of numbers that one of skill in the art would consider equivalent to the recited value (for example, having the same function or result). In many instances, the term "about" may include numbers that are rounded to the nearest significant figure.

In everyday usage, indefinite articles (like "a" or "an") precede countable nouns and noncountable nouns almost never take indefinite articles. It must be noted, therefore, that, as used in this specification and in the claims that follow, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a support" includes a plurality of supports. Particularly when a single countable noun is listed as an element in a claim, this specification will generally use a phrase such as "a single." For example, "a single support."

Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit (unless the context clearly dictates otherwise), between the upper and lower limit of that range, and any other stated or intervening value in that stated range, is encompassed within the disclosure. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges and are also encompassed within the disclosure, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure.

In this specification and in the claims that follow, reference will be made to a number of terms that shall be defined to have the following meanings unless a contrary intention is apparent.

Automated System

FIG. **1**A is an example according to various embodiments illustrating a side perspective view of an automated system **300** that is used to move a component **200** removably held by a gripping apparatus **100** in one or more directions. Components may include any small discrete parts that need to move from one area to another for further assembly or finishing operations. For example, components may include shaving razor components such as shaving cartridge housings, shaving razor connectors, shaving razor cartridge dispensers. In yet another example, components can have high surface complexity but are lightweight (e.g., less than or greater than about 5 grams) depending on the surface area. However, it is understood that components are not limited to shaving razor cartridges. In an embodiment, the gripping apparatus **100** includes a body **102** with a first end **108** that is attached to a component **302** of the automated system **300**. In one embodiment, the component **200** is removably held by a gripper head **120** secured to a second end **110** of the body **120** that is opposite to the first end **108**. In some embodiments, the component **200** is removably held by the gripper head **120** using an airflow supplied to the body **102** through a hose **301**. In one embodiment, the component **302** of the automated system **300** is configured to move in one or more directions. In an example embodiment, the component

302 is a pick and place device that is configured to move in one or two dimensions. As shown in FIG. 1A, the component 302 is configured to move in a plurality of directions (e.g. up to six directions) including along one or more axes 304*a*, 304*b*, 304*c* and/or in one or more rotational directions 305*a*, 305*b*, 305*c* about the respective axes 304*a*, 304*b*, 304*c*. In yet another example embodiment, the automated system 300 is a robotic system and the position of the component 302 is automatically adjusted by a controller (not shown).

FIG. 1B is an example according to various embodiments illustrating a top view of components 200 being moved from a first location to a second location with the automated system 300 of FIG. 1A. In one embodiment, the first location is a first conveyor line 310*a* and the second location is a second conveyor line 310*b*. In these embodiments, the component 302 and the gripping apparatus 100 are configured to move the components 200 from the first conveyor line 310*a* to the second conveyor line 310*b*. As shown in FIG. 1B, in some embodiments in addition to moving the components 200 from the first conveyor line 310*a* to the second conveyor line 310*b* the component 302 and the gripping apparatus 100 are configured to rearrange the components 200 as they are placed on the second conveyor line 310*b*. In an example embodiment, the component 302 and the gripping apparatus 100 are configured to move the components 200 from a random arrangement 320 on the first conveyor line 310 to an ordered arrangement 321 (e.g. aligned with an axis 312 along the second conveyor line 310*b*) on the second conveyor line 310*b*. Additionally, as shown in FIG. 1B the second conveyor line 310*b* includes one or more calibration locations 318*a*, 318*b* (whose location is known). As appreciated by one of ordinary skill in the art, the automated system 300 is calibrated by moving the component 302 to each of the one or more calibration locations 318*a*, 318*b* and recording a position of the component 302 at each calibration location 318*a*, 318*b* in a memory of the controller. These stored locations are then used by the automated system 300 to determine other locations on the second conveyor line 310*b* (e.g. other points along the axis 312).

Gripping Apparatus

The gripping apparatus 100 that was discussed with reference to FIG. 1A will now be described in more detail. FIG. 2 is an example according to various embodiments illustrating a sectional perspective view of the gripping apparatus 100 including the gripper head 120 that is used to releasably hold the component 200. In some embodiments, the gripping apparatus 100 is similar to the apparatus 100 depicted in FIG. 1A and includes bolts 103 provided at the first end 108 of the body 102 which are used to secure the body 102 to the component 302 of the automated system 300.

In an embodiment, the gripping apparatus 100 includes the body 102 that defines a chamber 104 and includes an exhaust 106 at the first end 108 of the body 102. The gripper head 120 is attached to the second end 110 of the body 102 that is opposite to the first end 108. In some embodiments, the second end 110 of the body 102 is removably attached to the gripper head 120 using one or more bolts 121 (e.g., that pass through aligned openings in the gripper head 120 and the body 102). As shown in FIG. 2, in some embodiments the bolts 121 are used to secure a first end 170 of the gripper head 120 to the second end 110. Although FIG. 2 depicts that bolts 121 are used to removably attach the gripper head 120 to the second end 110 of the body 102, any other means appreciated by one of ordinary skill in the art can be used to secure the gripper head 120 to the second end 110 (e.g. clips, magnets and/or an air vacuum).

As shown in FIG. 2, a second end 172 of the gripper head 120 that is opposite from the first end 170 defines an opening 122 and a nest 124 with a profile configured to locate and releasably hold the component 200 based on an air flow generated within the chamber 104 and discharged through the exhaust 106. Although a single opening 122 is depicted in the gripper head 120 of FIG. 2, in other embodiments the gripper head 120 features multiple openings. In one example embodiment, the nest 124 is rigid. In another example embodiment, the opening 122 and the nest 124 are configured such that the component 200 is held by the gripper head 120 at a maximum velocity or maximum inertia at which the automated system 300 operates. In this example embodiment, the design of the gripper head 120 advantageously ensures that the component 200 is not dropped by the gripper head 120 as it is transported from the first location (e.g. the conveyor line 310*a*) to the second location (e.g. conveyor line 310*b*) by the automated system 300.

Additionally, in an embodiment, the gripping apparatus 100 includes an air conveyor 140 positioned within the chamber 104. The air conveyor 140 generates the air flow through an inlet 144 and out through the exhaust 106. As previously discussed, in some embodiments the air flow is provided to the inlet 144 via the hose 301 that is connected to a compressed air source (not shown) of the automated system 300. As shown in FIG. 2, in one embodiment, the body 102 securely surrounds and encases the air conveyor 140 within the chamber 104.

FIG. 3A is an example according to various embodiments illustrating a cross-sectional side view of the gripping apparatus 100 including a gripper head 120*a* to releasably hold a component 200*a*. As shown in FIG. 3A, the nest 124 has a profile configured to locate and releasably hold the component 200*a* based on an air flow 142 generated within the chamber 104 and discharged through the exhaust 106. The air conveyor 140 defines a central bore 146 and an exhaust port 148. The inlet 144 includes an inlet port 145 with a nozzle 147 in communication with the central bore 146 and the exhaust port 148. As shown in FIG. 3A, in one embodiment the nozzle 147 and the inlet port 145 are oriented at a non-zero angle (e.g. orthogonal angle) to a longitudinal axis 150 of the air conveyor 140 defined by the central bore 146. As further shown in FIG. 3A, in an embodiment the exhaust port 148 of the air conveyor 140 is positioned at one end of the chamber 104 that is adjacent to the first end 108 of the body 102. Based on this arrangement, the exhaust 106 at the first end 108 of the body 102 is in communication with the exhaust port 148 and the central bore 146 of the air conveyor 140. Additionally, due to this arrangement, the air flow 142 generated within the central bore 146 is discharged through the exhaust 106 at the first end 108 of the body 102. FIG. 3A further depicts that in one embodiment the exhaust 106 at the first end 108 of the body 102 defines a plurality of exhaust openings 112*a* through 112*d*. As further shown in FIG. 3A the plurality of exhaust openings 112*a* through 112*d* are spaced apart along an outer surface 116 of the first end 108 of the body 102 such that the generated air flow 142 is dissipated through the plurality of exhaust openings 112*a* through 112*d*. In an example embodiment, where four exhaust openings 112*a* through 112*d* are provided, the exhaust openings are angularly spaced apart by about 90 degrees.

As shown in FIG. 3A, in an embodiment the gripper head 120*a* is secured to the second end 110 of the body 102 with an O-ring 119 that forms a vacuum seal between the gripper

head **120***a* and the second end **110** of the body **102**. In one embodiment, the gripper head **120***a* defines a recess **118** that is sized and shaped to receive the O-ring **119** in order to form the vacuum seal between the gripper head **120***a* and the second end **110** of the body **102** when the O-ring **119** is positioned in the recess **118** and the bolts **121** are secured through openings in both the gripper head **120***a* and the second end **110** of the body **102**. Although an O-ring **119** is depicted in FIG. **3**A, in other embodiments any means can be used to form a vacuum seal between the gripper head **120***a* and the second end **110** of the body **102**. Additionally, as shown in FIG. **3**A in one embodiment the gripper head **120***a* defines an inner conical surface **174** over which the recess **118** is formed.

First Gripper Head Design

A first embodiment of the gripper head **120***a* and associated component **200***a* located and releasably held by the gripper head **120***a* will now be discussed and is depicted in FIGS. **3**B through **3**D. In an embodiment, the component **200***a* may include a shaving razor cartridge cover configured to hold a shaving razor cartridge.

FIGS. **3**B through **3**D is an example according to various embodiments illustrating perspective views of the gripper head **120***a* of FIG. **3**A that is used to releasably hold the component **200***a*. As shown in FIG. **3**A, in one embodiment the gripper head **120***a* defines a single opening **122***a* that is parallel to a longitudinal axis **126** of the gripper head **120***a*. The single opening **122***a* and the nest **124***a* are configured to locate and releasably hold the component **200***a* based on the generated air flow **142**. In an example embodiment, a width of the single opening **122***a* is non-tapered over the gripper head **120***a*. (FIG. **2**B, FIGS. **3**A-**3**C). In another example embodiment, the single opening **122***a* is circular in shape.

As shown in FIGS. **3**A and **3**D, in an embodiment the nest **124***a* of the gripper head **120***a* defines a profiled pocket **132** in communication with the single opening **122***a*. The profile pocket **132** is configured to receive a portion **204** of the component **200***a* releasably engaged by the gripper head **120***a*. As shown in FIG. **3**B, in some embodiments the profile pocket **132** is elongated along a transverse axis **127** that is orthogonal to the longitudinal axis **126** of the gripper head **120***a*. In an example embodiment, the profile pocket **132** is shaped based on a shape of the portion **204** of the component **200***a* that is received within the profile pocket **132**. In this example embodiment, an inner length and/or an inner width of the profile pocket **132** is based on a corresponding outer length and/or outer width of the portion **204** (e.g. the inner length and/or width of the profile pocket **132** is slightly larger so that the portion **204** fits within the profile pocket **132**).

The gripper head **120***a* was designed based on features of the component **200***a*. As previously discussed, in one embodiment the dimensions and shape of the profile pocket **132** are based on corresponding dimensions and shape of the portion **204** of the component **200***a* to be received in the profile pocket **132**. The shaping of the profile pocket **132** may advantageously assist the gripper head **120***a* to locate and receive the component **200***a* in the profile pocket **132**. Additionally, in another embodiment, the component **200***a* may not have openings (e.g., is solid throughout). Accordingly, the single opening **122***a* in the gripper head **120***a* may be positioned toward a center of the component **200***a* that is received in the profile pocket **132** to achieve a relatively equal distribution of suction force on the component **200***a* when the air flow **142** is generated in the body **102**. Accordingly, the position of the opening **122***a* may be designed based on the specific geometry of the component **200***a* to be picked up and moved (e.g., shape and location of any voids in the component **200** that make holding the component difficult).

Second Gripper Head Design

A second embodiment of a gripper head **120***b* and associated component **200***b* located and removably held by the gripper head **120***b* will now be discussed and are depicted in FIGS. **4**A through **4**D. In an embodiment, the component **200***b* may include a shaving razor cartridge housing.

FIG. **4**A is an example according to various embodiments illustrating a cross-sectional side view of the gripping apparatus **100** including a gripper head **120***b* to releasably hold a component **200***b*. With respect to the gripping apparatus **100**, FIG. **4**A depicts that the nozzle **147** has a diameter **162** that is less than a diameter **164** of the central bore **146**. The transition from the nozzle **147** to the central bore **146** is a venturi transition since the air flow **142** experiences a diameter transition from the nozzle **147** to the central bore **146**. Also as shown in FIG. **4**A, the central bore **146** has a diameter **166** adjacent a second end **110** of the body **102** that reduces to the diameter **164** adjacent a central portion of the central bore **146** and thus the air flow **142** passing from the bottom of the central bore **146** to central portion of the central bore **146** also experiences a venturi transition. As further shown in FIG. **4**A, in an embodiment the body **102** has an outer diameter **171** at the second end **110** that is greater than an outer diameter **173** of the gripper head **120** at a second end **172** where the nest **124** is formed. It was recognized that the outer diameter **173** should be sufficiently large in order to encompass the component **200** to be located and removably held by the nest **124** of the gripper head **120**.

As shown in FIG. **4**A, in an embodiment the gripper head **120***b* defines one or more openings that are different from the single opening **122***a* in the gripper head **120***a*. Additionally, in this embodiment the gripper head **120***b* defines a nest **124***b* which is different from the nest **124***a* of the gripper head **120***a*. In these embodiments the gripper head **120***b* has a different set of openings and nest since the gripper head **120***b* is configured to locate and releasably hold a component **200***b* with different characteristics from the component **200***a* located and releasably held by the gripper head **120***a*. In these embodiments, the gripper head **120***b* defines angled openings **134** that are angled relative to a longitudinal axis **126** of the gripper head **120***b*. In this embodiment, the angled openings **134** form an angle **138** with the longitudinal axis **126**. In an example embodiment, the angle **138** is in a range from 30 degrees to 60 degrees. In one embodiment, no specific value of the angle **138** is necessary since the angle **138** is for merging the paths of the air flow through the single opening **136** and the angled openings **134** based on a location of suction to be applied to the component **200***b*. In other embodiments, the value of the angle **138** is determined based on a clearance that is required for the automated system **300** employing the gripper head **120***b* to locate the component **200***b* within the recess **139** of the gripper head **120***b*. As further shown in FIG. **4**A, the gripper head **120***b* further defines a single opening **136** that is oriented parallel to the longitudinal axis **126**. In some embodiments, the angled openings **134** have a first width **135** and the single opening **136** has a second width **137** that is different from the first width **135**. In one example embodiment, the first width **135** is less than the second width **137**.

FIGS. **4**B through **4**D is an example according to various embodiments illustrating perspective views of the gripper head **120***b* of FIG. **4**A to releasably hold the component **200***b*. As further shown in FIG. **4**A, the nest **124***b* of the gripper head **120***a* defines a recess **139**. FIG. **4**C depicts that

in some embodiments the component **200***b* includes a solid portion **206** (e.g. not porous with no openings), a portion with openings **208** and a male portion **205**. In these embodiments, the recess **139** is shaped and sized to receive the male portion **205** of the component **200***b*.

As shown in FIGS. **4**B and **4**C, when the component **200***b* is releasably held by the gripper head **120***b* the angled openings **134** are aligned with the solid portion **206** of the component **200***b* and the single opening **136** is aligned with the openings **208** of the component **200***b*. The openings may be designed and sized to maximize force on a land (e.g., flat open space to apply suction force) on the component **200***b*. The particular arrangement of the openings **134**, **136** with the respective solid portion **206** and openings **208** of the component **200***b* may achieve certain advantages. For example, this particular arrangement may distribute a suction force across the component **200***b* (e.g. across the solid portion **206** and openings **208**) based on the generated air flow **142**. In this example embodiment, the wider opening **136** is aligned with the openings **208** and the narrower openings **134** are aligned with the solid portion **206** since a larger air flow is necessary across the openings **208** relative to the solid portion **206** in order to achieve an equalized suction force across the component **200***b*.

Third Gripper Head Design

A third embodiment of a gripper head **120***c* and associated component **200***c* located and removably held by the gripper head **120***c* will now be discussed and are depicted in FIGS. **5**A through **5**C. In an embodiment, the component **200***c* is another possible example of a shaving razor cartridge cover.

FIG. **5**A is an example according to various embodiments illustrating a cross-sectional side view of the gripping apparatus **100** including the gripper head **120***c* to releasably hold the component **200***c*. FIGS. **5**B through **5**C is an example according to various embodiments illustrating perspective views of the gripper head **120***c* of FIG. **5**A to releasably hold the component **200***c*. As shown in FIG. **5**A, the gripper head **120***c* includes a single opening **122***c*. In one embodiment, unlike the single opening **122***a* of FIG. **3**A (non-tapered width), the width of the single opening **122***c* is tapered over the gripper head **120***c*.

Additionally, as shown in FIG. **5**A, in some embodiments the gripper head **120***c* and the single opening **122***c* are elongated along a transverse axis **127** of the gripper head **120***c* that is orthogonal to the longitudinal axis **126**. In an embodiment, the elongated single opening **122***c* is dimensioned to distribute a suction force across the component **200***c* along the transverse axis **127** based on the generated air flow **142**. The nest **124***c* of the gripper head **120***c* is a profiled surface **130** that is elongated along the traverse axis **127**. The profiled surface **130** is dimensioned along the transverse axis **127** based on a corresponding inner diameter of a recess **202** of the component **200***c* along the transverse axis **127**. Additionally, as shown in FIG. **5**C, the profiled surface **130** is configured to be received within the recess **202** defined by the component **200***c*. In an example embodiment, an outer diameter of the profiled surface **130** along the transverse axis **127** is less than an inner diameter of the recess **202** along the transverse axis **127** but is sufficiently close to the inner diameter of the recess **202** in order to achieve a close fit of the profiled surface **130** within the recess **202**.

The gripper head **120***c* was designed with these particular features (e.g. elongated opening **122***c* along the transverse axis **127** and/or elongated profiled surface **130** along the transverse axis **127**) to achieve one or more advantages with respect to locating and removably holding the component **200***c*. The single opening **122***c* and the profiled surface **130** may be shaped and dimensioned along the transverse axis **127** to advantageously enhance the fit of the profile surface **130** within the recess **202** and further distributes the suction force on the component **200***c* across the transverse axis **127**.

Gripper Head Kit

Although the previously discussed embodiments disclose the gripping apparatus **100** that includes the body **102**, the present invention is not limited to these embodiments and in some embodiments includes a kit is provided that can be used with the gripping apparatus **100** in order to secure different gripper heads **120** to the body **102** in order to move different types of components **200** from the first location to the second location. This advantageously permits the same gripping apparatus **100** and body **102** that can otherwise only transport one type of component to be converted into an improved gripping apparatus that can be used to transport multiple different types of components by securing different gripper heads to the body **102** of the gripping apparatus **100**.

FIG. **6** is an example according to various embodiments illustrating a kit **350** for the gripping apparatus **100** including multiple gripper heads **120***a*, **120***b*, **120***c* used to transport multiple components **200***a*, **200***b*, **200***c* from a first location to a second location. Although three gripper heads **120***a*, **120***b*, **120***c* are depicted in FIG. **6**, the kit **350** is not limited to including one or more of these gripper heads **120***a*, **120***b*, **120***c* and includes other gripper heads with a different design that can be similarly employed to locate and releasably hold different components other than the components **200***a*, **200***b*, **200***c*.

In some embodiments, as shown in FIG. **6** the kit **350** includes a calibration tip **125**. In these embodiments, the calibration tip **125** can be secured to the second end **110** of the body **102** in a similar manner as the gripper heads **120** (e.g. passing bolts **121** through aligned openings in the calibration tip **125** and the second end **110** of the body **102**). This calibration tip **125** can then be used to calibrate a position of the system in which the gripping apparatus **100** is employed. In one example embodiment, FIG. **1**C depicts a pair of calibration locations **318***a*, **318***b* on the second conveyor line **310***b*. In order to calibrate the location of the gripping apparatus **100** within the automated system **300** the calibration tip **125** is secured to the second end **110** of the body **102** after which the body **102** is moved by the component **302** of the automated system **300** until the calibration tip **125** is at each calibration location **318***a*, **318***b*. A controller (not shown) of the automated system **300** then stores the position of the calibration tip **125** in a memory which is then used in positioning the body **102** with the attached gripper head **120** at one or more other locations on the second conveyor line **310***b*.

As further shown in FIG. **6**, in some embodiments the kit **350** includes one or more components to facilitate removing a first gripper head **120***a* from the second end **110** of the body **102** and securing a second gripper head **120***b* (different from the first gripper head **120***a*) to the second end **110** of the body **102**. This advantageously facilities the same gripping apparatus **100** being used to transport one or more components **200***a* (with the gripper head **120***a*) from the first location to the second location and after which being used to transport one or more components **200***b* (with the gripper head **120***b*) from the first location to the second location. Although the gripper heads **120***a*, **120***b* and components **200***a*, **200***b* are discussed in this embodiment, the kit is not limited to these gripper heads and components and thus can facilitate the removal and replacement of any two different gripper heads in order to facilitate the transport of any two

different components which can be located and releasably held by the two different gripper heads.

In some embodiments, the components used to facilitate the removal and replacement of gripper heads **120** from the second end **110** of the body **102** include the O-ring **119** and the bolts **121**. In these embodiments, the first gripper head **120***a* is removed by removing the bolts **121** from the second end **110** of the body **102** and removing the O-ring **119** from the recess **118** in the first gripper head **120***a*. The O-ring **119** is then positioned in the recess **118** of the second gripper head **120***b*. The bolt openings of the second gripper head **120***b* are then aligned with the bolt openings in the second end **110** of the body **102** and the bolts **121** are passed through the aligned openings to secure the second gripper head **120***b* to the second end **110** of the body **102**. These steps can be repeated in order to replace any gripper head with another gripper head, and thus facilitates the versatility of the gripping apparatus **100** being used to transport multiple different types of components **200**. However, although the O-ring **119** and bolts **121** are depicted in FIG. **6**, the kit **350** is not limited to these particular components for removing and replacing the gripper head and in other embodiments includes other components or means (e.g. clips, magnetic or an air vacuum) for removing and replacing the gripper heads.

Method for Transporting Components Using Multiple Gripper Heads

A method is now presented where the gripper apparatus **100** and the one or more gripper heads **120** are used to transport one or more components **200** from the first location to the second location. FIG. **7** is an example according to various embodiments illustrating a flowchart of a method **400** for transporting one or more components **200** using the one or more gripper heads **120** of the kit **350** of FIG. **6**. In one embodiment, the method **400** is used to transport one or more components from the first conveyor line **310***a* to the second conveyor line **310***b* (FIG. **1**B). Although the flow diagram of FIG. **7** is depicted as integral steps in a particular order for purposes of illustration, in other embodiments, one or more steps, or portions thereof, are performed in a different order, or overlapping in time, in series or in parallel, or are omitted, or one or more additional steps are added, or the method is changed in some combination of ways.

The method **400** begins at step **401** where the gripper head **120** is selected to transport the one or more components **200**. In one embodiment, in step **401** one or more characteristics of the components **200** are determined and are used to select the gripper head **120**. In one example embodiment, in step **401** the gripper head **120***a* is selected in order to transport one or more components **200***a*. In another example embodiment, in step **401** the gripper head **120***b* is selected in order to transport one or more components **200***b*. In one example embodiment, in step **401** the gripper head **120***c* is selected in order to transport one or more components **200***c*. However, step **401** is not limited to selecting among the gripper heads **120***a*, **120***b*, **120***c* to transport the components **200***a*, **200***b*, **200***c*, and includes other gripper heads **120** that are designed in a similar manner as the gripper heads **120***a*, **120***b*, **120***c* to transport components **200** other than the components **200***a*, **200***b*, **200***c*.

The method **400** then proceeds to step **402** where the gripper head **120** selected in step **401** is secured to the second end **110** of the body **102** of the gripper apparatus **100**. In one embodiment, in step **402** the O-ring **119** is positioned in the recess **118** of the gripper head **120**. The bolt openings in the gripper head **120** are then aligned with corresponding bolt openings in the second end **110** of the body **102**. The bolts **121** are then passed through the aligned bolt openings to secure the gripper head **120** to the second end **110** of the body **102**. It was recognized that step **402** secures the gripper head **120** to the second end **110** of the body **102** to form a vacuum seal between the gripper head **120** and the second end **110** such that air does not pass between the gripper head **120** and the second end **110** of the body **102**. In other embodiments, other means are employed in step **402** to secure the gripper head **120** to the second end **110** of the body **102** (e.g. clips, magnets or a vacuum source). In one example embodiment, in step **402** the gripper head **120***a* with the single opening **122***a* and the nest **124***a* is attached to the second end **110** of the body **102**.

The method **400** then proceeds to step **404** where the air flow **142** is generated through the inlet **144** of the air conveyor **140** and out through the exhaust **106** at the first end **108** of the body **102**. In some embodiments, in step **404** a compressed air source (not shown) supplies the air flow **142** through the hose **301** (FIG. **1**A) to the inlet **144**. In some embodiments, in step **404** a pressure of the compressed air is selected (e.g. between 4 bar, 5 bar and 6 bar) that is supplied to the inlet **144** from the compressed air source. In these embodiments, the value of the pressure is selected based on one or more characteristics of the component **200**.

The method **400** then proceeds to step **406** where suction force is applied to the component **200** through the gripper head **120** so that the nest **124** of the gripper head **120** locates and releasably holds the component **200**. In some embodiments, step **406** is performed to the component(s) **200** located at the first location (e.g. first conveyor line **310***a*). This suction force is applied through the gripper head **120** due to the generated air flow **142** at step **404**. In an example embodiment, where the gripper head **120***a* is attached to the second end **110** of the body **102** in step **402**, in step **406** suction is applied to the component **200***a* via the single opening **122***a* to releasably hold the component **200***a* with the gripper head **120***a* at the first location. Additionally, in this example embodiment, the applying step **406** includes the male portion **204** of the component **200***a* being received within the profiled pocket **132** of the gripper head **120***a* to releasably hold the component **200***a* with the gripper head **120***a*.

In another example embodiment, where the second gripper head **120***b* is attached to the second end **110** of the body **102** in step **402**, in step **406** suction is applied to the component **200***b* via the angled openings **134** and the single opening **136** to releasably hold the second component **200***b* based on the generating step **404**. Additionally, in this example embodiment, the angled openings **134** are aligned with the solid portion **206** of the component **200***b* and the single opening **136** is oriented at the openings **208** of the component **200***b* such that the applying step **406** distributes a suction force across the solid portion **206** and openings **208** of the component **200***b* based on the generating step **404**.

In yet another example embodiment, when the gripper head **120***c* is attached to the second end **110** of the body **102**, the elongated single opening **122***c* is dimensioned such that the applying step **406** distributes a suction force across the component **200***c* along the transverse axis **127** based on the generating **404** step. Additionally, in this example embodiment, the applying step **406** causes the profiled surface **130** of the component **120***c* to be received within the recess **202** defined by the component **200***c*.

The method **400** then proceeds to step **408** where the component **200** releasably held by the gripper head **120** at the first location in step **406** is transported to a second

location. In one embodiment, where the gripping apparatus **100** is secured to the component **302** of the automated system **300**, in step **408** the component **302** of the automated system **300** is moved in one or more directions (e.g. along one or more axes **304***a*, **304***b*, **304***c* and/or in one or more rotational directions **305***a*, **305***b*, **305***c*) until the component **200** is at the second location (e.g. second conveyor line **310***b*). In this example embodiment, in step **408** the component **302** is moved until the component **200** is at a particular location at the second location (e.g. along axis **312** of the second conveyor line **310***b*) so that the components **200** are arranged with a particular arrangement at the second location (e.g. ordered arrangement **321** along the axis **312**).

The method **400** then moves to block **310** where it is determined whether more components **200** of the same type moved in step **308** are to be moved. If the result of this determination is in the affirmative, the method **400** proceeds back to step **404** and steps **404** through **408** are repeated for another component **200** of the same type moved in step **408**. This is repeated until all of the components **200** of the same type are moved from the first location to the second location. If the determination is in the negative, the method **400** proceeds to block **412**.

In block **412**, the method **400** determines whether additional components **200** other than the component **200** moved in the previous iteration of step **408** are to be moved. If the result of this determination is in the affirmative, the method **400** moves to step **413**. If the result of this this determination is in the negative, the method **400** ends since no more components **200** are to be moved from the first location to the second location.

In step **413**, the method **400** removes the gripper head **120** that is secured to the second end **110** of the body **102**. In an embodiment, step **413** is performed after all components **200** to be moved by the gripper head **120** have been moved from the first location to the second location and more components **200** of a different type still need to be transported from the first location to the second location. For purposes of description, step **413** will be discussed with respect to removing the gripper head **120***a* which is performed after transporting the components **200***a* from the first location to the second location. In this example embodiment, step **413** is performed after all of the components **200***a* are moved with the gripper head **120***a*. In one embodiment, in step **413** the bolts **121** are removed from the second end **110** of the body **102** and the gripper head **120***a* is removed from the second end **110**. The O-ring **119** is also removed from the recess **118** of the gripper head **120***a*.

After step **413** the method **400** proceeds back to steps **401** and **402** where the gripper head **120** is replaced with a different gripper head **120** in order to move components **200** that are different from the components **200** moved by the gripper head **120** removed in step **413**. In the above example embodiment, after removing the gripper head **120***a* in step **413** the gripper head **120***b* is selected in step **401** due to components **200***b* which need to be transported from the first location to the second location. In this example embodiment, in step **402** the O-ring **119** is inserted in the recess **118** of the gripper head **120***b*. The gripper head **120***b* is then secured to the second end **110** of the body **102** using the bolts **121**. Although steps **401** and **402** are discussed in the context of the example of replacing the gripper head **120***a* with the gripper head **120***b*, these steps can be similarly performed when replacing any gripper head with a different gripper head. After the gripper head **120***b* is attached in the second iteration of step **402**, steps **404** through **408** are performed to transport the components **200***b* from the first location to the second location.

System and Method for 3D Printing Gripper Heads for Transporting Components

A system and method will now be discussed that is used to 3D print one or more of the gripper heads **120** that are used to transport the one or more components **200**. FIG. **8** is an example according to various embodiments illustrating a system **500** for 3D printing one or more gripper heads **120** of the kit **350** of FIG. **6**. In an embodiment, the system **500** includes a 3D printer **502** that is used to 3D print one or more of the components **200**. The system **500** also includes a controller **504** with a memory **505** that is communicatively coupled to the 3D printer **502**. In some embodiments, the system **500** also includes a scanner **506** is used to scan one or more of the components **200**. The scanner **506** is communicatively coupled to the controller **504** and is configured to transmit scan data (e.g. CAD data) of the component **200** to the controller **504**. The scan data indicates the geometry of the component **200** which is used by the controller **504** to obtain data (e.g. CAD data) indicating a geometry of a gripper head **120** that can be used to locate and releasably hold the component **200**.

In an example embodiment, a correspondence between the geometry data of the component **200** and the geometry data of the gripper head **120** is stored in the memory **505** of the controller **504**. In this example embodiment, the controller **504** determines the geometry data of the gripper head **120** to be 3D printed from the memory **505** based on the geometry data of the component **200** that is received from the scanner **506** (or from another remote data source). In some embodiments, the controller **504** transmits this data indicating the geometry of the gripper head **120** to the 3D printer **502** which then 3D prints the gripper head **120** to be used in transporting the component **200**. In other embodiments, the data indicating the geometry of the component **200** and/or the gripper head **120** is downloaded to the memory **505** of the controller **504** from a remote source. In these embodiments, the scanner **506** is not used since the data indicating the geometry of the gripper head **120** is downloaded from a remote source other than the scanner **506**.

FIG. **9** is an example according to various embodiments illustrating a flowchart of a method **550** for forming the one or more gripper heads **120** using the system **500** of FIG. **8**. In an embodiment, the method **550** includes obtaining **552** 3D data (e.g. CAD data) based on a geometry of a component **200**. As previously discussed, in some embodiments step **552** is performed using the scanner **506** which scans a component **200** to be transported by the gripping apparatus **100**. The scanner **506** scans the component **200** to obtain data (e.g. CAD data) indicating a geometry of the component **200**. This data is then transmitted from the scanner **506** to the controller **504** which determines corresponding data indicating a geometry of a gripper head **120** to be used to transport the component **200**. In one example embodiment, the memory **505** of the controller **504** stores a correspondence between the geometry data of the component **200** and the geometry data of the gripper head **120** to be used to transport the component **200**. Thus, the controller **504** uses the memory **505** to determine the geometry data of the gripper head **120** based on the received geometry data of the component **200**.

In some embodiments, the 3D data obtained in step **502** indicates solid regions and openings of the component **200**. In one embodiment, for the component **200***b* the 3D data

obtained in step **502** indicates the solid regions **206** and the openings **208** in the component **200***b*. The controller **504** uses this obtained 3D data to determine the data indicating the geometry of the gripper head **120***b* (e.g. with the angled openings **134** and single opening **136**) to locate and releasably hold the component **200***b*. In one example embodiment, the controller **504** determines the data indicating the geometry of the gripper head **120***b* by positioning the angled openings **134** to be aligned with the openings **208** and the single opening **136** to be aligned with the solid portions **206** of the component **200***b*. As previously discussed, this geometry of the gripper head **120***b* achieves notable advantages, such as distributing the suction force across the component **200***b*.

In step **554**, the method **550** includes a step of forming the gripper head **120** based on the 3D data obtained in step **552**. In an embodiment, in step **554** the 3D printer **502** forms the gripper head **120** based on the geometry data of the gripper head **120** received from the controller **504**. In one embodiment, in step **554** the 3D printer **502** forms the nest **124** and the one or more openings **122** in the gripper head **120**. It was recognized that the 3D printing advantageously permits the gripper head **120** to be formed with intricate curvatures and openings (e.g. angled opening **134** in FIG. **4**D) that would not be possible with conventional manufacturing methods (e.g. injection molding, machining, etc.). In one example embodiment, in step **554** the 3D printer **502** forms the nest **124** and the one or more openings **122** in the gripper head **120** to locate and releasably hold the component **200** based on suction being applied through the one or more openings **122**.

In one example embodiment, the 3D printing in step **554** is performed using 3D printable material (e.g. one of carbon fiber, metal, polymer and impregnated polymer material). Additionally, in another example embodiment, the 3D printing in step **554** is performed such that the 3D printed gripper head **120** has a weight in a range between 0.1 kg and 0.5 kg.

The formation of the different gripper head designs **120***a*, **120***b*, **120***c* will now be discussed based on the method **550** of FIG. **9**. In one example embodiment of the gripper head **120***a*, the obtaining step **502** includes obtaining 3D data indicating the geometry of the component **200***a*. In one embodiment the obtaining step **502** includes identifying the male portion **204** of the component **200***a*. In this embodiment, the forming step **504** includes forming the nest **124** of the gripper head **120***a* with the profiled pocket **132** in communication with the opening **122***a* such that the male portion **204** of the component **200***a* is received within the profiled pocket **132** based on suction applied through the opening **122***a*. The forming step **504** also includes forming the single opening **122***a* in the gripper head **120***a* that is parallel to the longitudinal axis **126** of the gripper head **120***a* so that the gripper head **120***a* is configured to releasably hold the component **200***a* based on suction applied through the opening **122***a*. In another embodiment, the forming step **504** includes forming the opening **122***a* with a fixed width over the gripper head **120***a*.

In one example embodiment of the gripper head **120***b*, the obtaining step **502** includes obtaining 3D data indicating the geometry of the component **200***b*. In one example embodiment, the obtaining step **502** includes obtaining 3D data that indicates the solid portion **206** and openings **208** of the component **200***b*. In this example embodiment, the forming step **504** includes orienting the multiple angled openings **134** such that they are aligned with the solid portion **206** of the component **200***b* and orienting the single opening **136** such that it is aligned with the openings **208** of the component **200***b* to distribute a suction force across the solid portion and openings **206**, **208** of the component **200***b* upon applying suction via the multiple angled openings **134** and the single opening **136**. In yet another example embodiment, step **504** includes sizing the multiple angled openings **134** with the first width **135** and sizing the single opening **136** with the second width **137** that is different (e.g. greater than) from the first width **135**. In some embodiments, the forming step **504** includes forming the single opening **136** in the gripper head **120***b* that is parallel to the longitudinal axis **126** such that the component **200***b* is releasably held by the gripper head **120***b* upon applying suction via the single opening **136** and the multiple angled openings **134**. Additionally, the forming step **504** involves forming the recess **139** in the gripper head **120***b* to receive the male portion **205** of the component **200***b*.

In one example embodiment of the gripper head **120***c*, the obtaining step **502** includes obtaining 3D data indicating the geometry of the component **200***c*. In some embodiments, the obtaining step **502** includes obtaining 3D data that indicates the recess **202** defined by the component **200***c*. In an embodiment, the forming step **504** includes forming the profiled surface **130** in the gripper head **120***c* that is elongated along the transverse axis **127** and is in communication with the opening **122***c* so that the profiled surface **130** is received within the recess **202** of the component **200***c* based on suction applied through the opening **122***c*. In another embodiment, the forming step **504** then includes forming the opening **122***c* including tapering a width of the opening **122***c* over the gripper head **120***c*. Additionally, in some embodiments, the forming step **504** includes elongating the opening **122***c* along the transverse axis **127** of the gripper head **120***c* that is orthogonal to the longitudinal axis **126**. In these embodiments, the forming step **504** further includes dimensioning the elongated opening **122***c* such that the suction applied through the elongated opening **122***c* is distributed across the component **200***c* along the transverse axis **127**.

In some embodiments, after a gripper head is formed in step **554**, in step **556** a determination is made of whether more components are to be transported other than the component for which the gripper head **120** was formed in step **554**. In an embodiment, in step **556** a determination is made whether a different type of component **200** needs to be transported other than the component **200** for which the gripper head **120** was formed in the previous iteration of steps **552** and **554**. If this determination is in the affirmative, then the method **550** proceeds back to step **552**. If the determination is in the negative, the method **550** ends.

Further Definitions and Cross-References

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "40 mm" is intended to mean "about 40 mm."

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definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

What is claimed is:

1. A method for transporting components from a first location to a second location using a gripping apparatus including a body defining a chamber and including an exhaust at a first end of the body and an air conveyor positioned within the chamber, the method comprising:

attaching one of a plurality of gripper heads to a second end of the body opposite to the first end, wherein the one of the plurality of gripper heads defines one or more openings and a nest;

generating an air flow through an inlet of the air conveyor and out through the exhaust;

applying suction via the one or more openings in the gripper head to locate and releasably hold one of the plurality of components with the griper head at the first location based on the generating step; and

transporting the one of the plurality of components releasably held to the gripper head from the first location to a second location, wherein the attaching step comprises attaching a first gripper head of the plurality of gripper heads having one or more first openings and a first nest to the second end of the body and wherein the applying suction step comprises applying suction via the one or more first openings to releasably hold a first component of the plurality of components with the first gripper head at the first location and wherein the transporting step comprises transporting the first component releasably held with the first gripper head from the first location to the second location; and wherein the method further comprises:

removing the first gripper head from the second end of the body;

attaching a second griper head of the plurality of gripper heads to the second end that is different from the first gripper head, wherein the second gripper head has one or more second openings and a second nest that is different from the one or more first openings and the first nest;

applying suction via the one or more second openings to releasably hold the second component with the second gripper head at the first location; and

transporting the second component releasably held to the second gripper head from the first location to the second location, wherein the first gripper head defines a single opening that is parallel to a longitudinal axis of the gripper head, wherein the applying step applies suction via the single opening to releasably hold the first component based on the generating step; and wherein the second gripper head defines multiple openings including one or more angled openings that are angled relative to a longitudinal axis of the second gripper head and wherein the applying step applies suction via the angled openings to releasably hold the second component based on the generating step.

2. The method of claim **1**, wherein the attaching step comprises attaching the gripper head to the second end using one or more of bolts, clips, magnetic or an air vacuum.

3. The method of claim **1**, wherein a width of the single opening is tapered over the first gripper head.

4. The method of claim **1**, wherein a width of the single opening is non-tapered over the first gripper head.

5. The method of claim **1**, wherein the single opening is elongated along a transverse axis of the first gripper head that is orthogonal to the longitudinal axis.

6. The method of claim **5**, wherein said elongated single opening is dimensioned such that the applying step comprises distributing a suction force across the first component along the transverse axis based on the generating step.

7. The method of claim **1**, wherein the nest of the first griper head is a profiled surface that is elongated along a traverse axis that is orthogonal to the longitudinal axis and is in communication with the single opening, wherein the applying suction step comprises receiving the profiled surface within a recess defined by the first component.

8. The method of claim **1**, wherein the single opening is circular in shape.

9. The method of claim **1**, wherein the nest of the first gripper head includes a profiled pocket in communication with the single opening, wherein the applying suction step comprises receiving a portion of the first component within the profiled pocket to releasably hold the first component with the first gripper head.

10. The method of claim **1**, wherein the one or more angled openings are multiple angled openings which form an angle with the longitudinal axis in a range from about 30 degrees to about 60 degrees.

11. The method of claim **10**, wherein the one or more openings further include a single opening that is parallel to the longitudinal axis such that the applying step comprises applying suction via the single opening and the one or more angled openings to releasably hold the second component based on the generating step.

12. The method of claim **11**, wherein the one or more angled openings are aligned with a solid portion of the second component and wherein the single opening is oriented at openings of the second component such that the applying step comprises distributing a suction force across the solid portion and openings of the second component based on the generating step.

13. The method of claim **12**, wherein the one or more angled openings have a first width and the single opening has a second width that is different from the first width.

14. The method of claim **13**, wherein the first width is less than the second width and wherein the solid portion of the second component is non-porous.

15. The method of claim **1**, wherein the one or more openings and the nest of the gripper head is configured such that the component releasably engaged by the gripper head has a maximum inertia below a threshold value and a maximum vacuum below a threshold value during the transporting step.

16. The method of claim **1**, wherein the body is attached to a pick and place device that is configured to move in one or more dimensions and wherein the transporting step comprises moving the pick and place device with the attached body and the component releasably held by the gripper head from the first location to the second location.

17. The method of claim **16**, wherein the pick and place device is a multi-axial programmable motion mechanism

that is configured to move along one of three axes and is further configured to rotate in one of three directions about one of the three axes.

18. The method of claim **1**, wherein the plurality of components each have one or more openings.

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